Allied's

RADIO BUILDER'S HANDBOOK

ALLIED RADIO CORPORATION

CHICAGO

RADIO BUILDER'S HANDBOOK

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A Simplified Radio
Handbook for Beginners
and Experimenters

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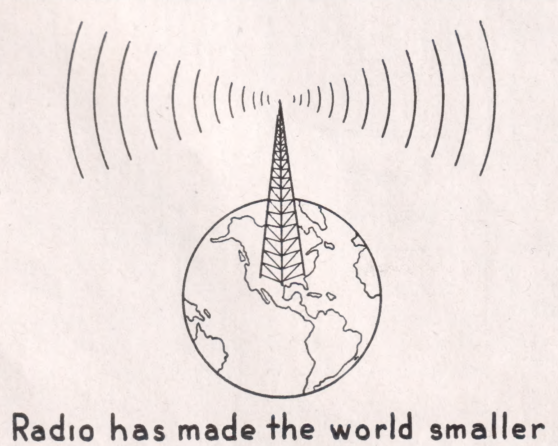
HOW RADIO EARNED ITS PLACE IN THE SUN

When Guglielmo Marconi finally succeeded in 1895 in transmitting a "wireless" message over a distance of a mile and a half, he set in motion a chain of development that has revolutionized the art of communication. Marconi did not "invent" radio nor was he alone in the early work in this new art. Yet from that small beginning, radio has steadily advanced to the point where today it provides communication facilities across continents and oceans, furnishes entertainment and instructions to millions of people, saves lives at sea and on land, aids police authorities in enforcing the law, transmits news dispatches to the daily press, guides airplanes along the skyways, and in a hundred other ways serves mankind and aids the progress of civilization.

We shall not attempt here to trace the history of the development of radio. There are dozens of good books and articles on the subject. A half hour spent in reading even an encyclopedia article on the subject will tell you more than we can say in our limited space. Suffice it to say, however, that the history of radio in the past forty years has been a history of perseverance against obstacles, of unstinted toil by thousands of plodding workers in the vanguard of science. It is a heroic story—one well worth studying.

Radio has made the world smaller. It has linked far-flung countries. It has brought to all of us—in the comfort of our homes—the leaders of the world in politics, science, drama, music, literature, art, and every other field of endeavor. It has made London and Paris and Rome and Buenos Aires and Sydney, Australia, as close to us as the switch on our short-wave set. Radio has proved itself as the greatest force in the twentieth century for bringing knowledge, pleasure, and joy to all of mankind.



Radio has made the world smaller

RADIO IS A FASCINATING HOBBY – EASY TO LEARN

The average radio listener regards radio as a deep and dark mystery. He is content merely to twirl a dial (or, now, to push a button) and to sit back quietly and be entertained. If something goes wrong in what he calls the "works" he is positively baffled and has to call in a radio serviceman.

But radio need not be a deep and dark mystery. To thousands of government licensed Amateurs and to multitudes of experimenters and radio builders, radio is a fascinating hobby that gives endless hours of real thrills, a vast store of useful knowledge, and the deep satisfaction of knowing that the radio equipment one has built by himself will really work.

To you, therefore, who are interested in the science of radio—in learning how to build practical radio circuits, in understanding some of the fundamentals of radio—this book is addressed. We have not attempted to make this an exhaustive complicated treatise. We think that you will get more real help by covering thoroughly only those basic details and practical applications that will be of real use to you. Our aim, in short, has been to give you a good working knowledge of radio building and experimentation, and to set you on the right path toward more advanced work.

If you turn ahead right now to look through the later pages of this book, you will probably feel bewildered at what seem to be complicated diagrams and tables. You may even say to yourself, "Well, this looks much harder than I expected. Maybe I've tried to tackle too much." But if you will read through these earlier pages, if you will study each section thoroughly before you go on to the next, you will be fully prepared for the constructional material by the time you get to it.

WHAT IS A RADIO SIGNAL?

Before going any farther, let's get a short word picture of what goes on in the air that brings music and speech to your earphones or loudspeaker. Let's take a short trip to a modern broadcast station. The voice of an artist singing before a microphone causes vibrations on the microphone diaphragm which are converted to electrical impulses. These impulses, called "audio frequency" impulses, are amplified millions of times and combined in the transmitter with a powerful "radio frequency" current called the "carrier". Now we have what engineers call a "modulated carrier."

The modulated carrier radiates in all directions from the station's antenna, reaching into the four corners of the earth. It does this by setting up vibrations in the ether which expand in a circular direction, much in appearance like the waves produced in a pond of still water when a stone is thrown into it.

Although thousands of watts of power may be radiated by the station antenna, most of this energy is lost in space; and only a small portion of it, a few millionths of a volt, enters your receiver. Your receiver amplifies this feeble signal, converts it into audio impulses again which vibrate the diaphragms of your ear phones or speaker, bringing to you the program which was presented in the studio.

All this happens in a fraction of a second. With the speed of electricity at 186,000 miles a second, you can readily see how quickly this takes place. Actually you hear the broadcast program from your radio before the audience hears it in the studio. This is because sound waves travel through the air at the rate of only 1,086 feet per second as compared with the speed of radio waves.

OTHER KINDS OF TRANSMISSION

Besides the familiar broadcast type of transmission explained above, there are other types used for special purposes. Code (C.W.) transmitters need only the R.F. sections in the diagram below. The carrier is broken into dots and dashes by means of a telegraph key and relays. It is heard in the receiver (if it is of the regenerative type) as an intermittent tone or whistle. Another but less common type of code transmission does make use of a modulator. In this method a "tone oscillator" is keyed.

Television transmission and reception uses the "modulated carrier" method also. The newest type of transmission which has been developed is called "frequency modulation." This type is used for speech and music and is commonly known as "staticless radio." It requires a fundamentally different type receiver than ever used before. As in television, an explanation of the theory of "frequency modulation" would be too involved for the purpose of this handbook.

We can only mention here that the radius of "frequency modulation" (FM) transmission is 50 to 100 miles. FM radio sets for some time, therefore, will be useful only in or near metropolitan areas where FM stations are located.

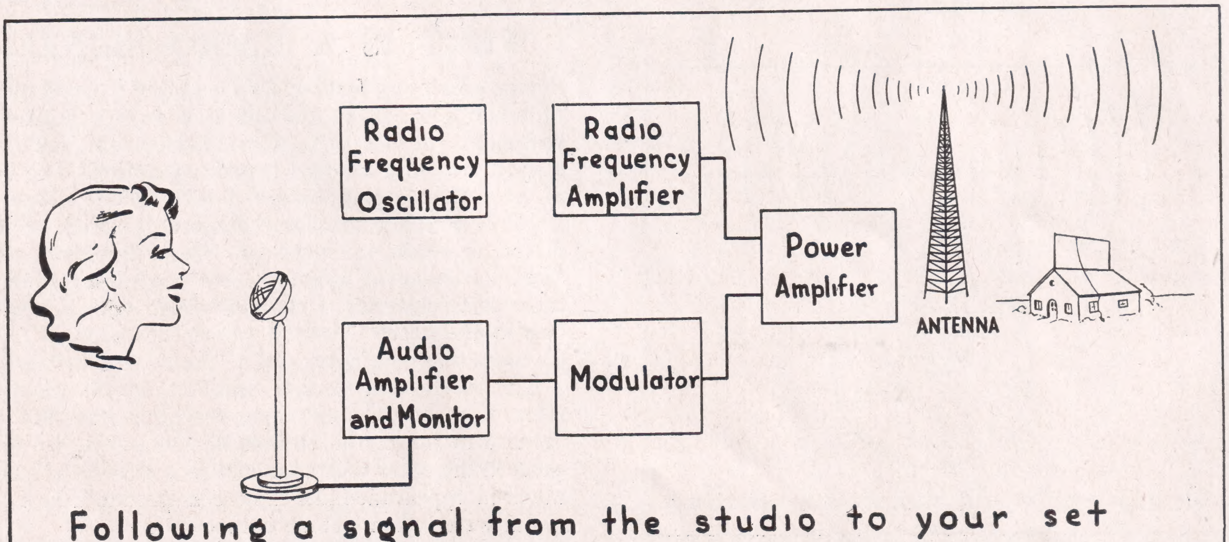
THE EXPERIMENTER-BUILDER AND WHAT HE DOES

No matter how far radio progresses, there will always be a place for the experimenter-builder. He is the fellow who tries out new circuit designs and new gadgets. Sometimes he stumbles across a new idea that is of distinct value to radio manufacturers. Sometimes he plans a career for himself as a future radio engineer or a radio servicing expert. Sometimes he decides to make radio a hobby, becomes an Amateur and goes on the air with his own transmitter.

But generally, the experimenter-builder is a radio "fan." He is in radio because he likes it—because he likes to build his own sets, experiment with circuit layouts, and try to improve the results he gets. True, he could buy a ready-built set and let his pleasure come only in listening to what's on the air. But the real "fan"—the true "Radio Bug"—is the fellow who gets as much pleasure out of building his set as he does later on in operating it.

It is safe to say that there are hundreds of thousands of these experimenter-builders in the United States. Perhaps you know several fellows yourself who have set up a little radio workshop somewhere in a basement, a garage, or a bedroom. Perhaps it is because of your acquaintance with one of these fellows that you yourself have become interested in radio. Whatever your reason for taking up radio and whatever the facilities you have available for work, you will get as much out of your hobby as you put into it. If, some day, you can turn your hobby into your profession, all the better. But even if your interest in radio remains a hobby you will get from it the advantages of acquiring some mechanical skill, using tools properly, joining a wide fellowship of friendly men and boys, developing your ingenuity, and doing real, constructive work.

Radio need not be an expensive hobby. The tools required for the beginner are few and inexpensive. And parts used in building any one circuit can almost always be used again in many other circuits.



Following a signal from the studio to your set

GETTING A START IN RADIO BUILDING

There are really two chief ways of learning any new handicraft or hobby. One is to begin by reading all of the theoretical discussions, plodding on through page after page of material that becomes very involved and seems almost useless, and finally after many weeks of study, arriving at a point where some of this great mass of information can be put to practical use. For the expert radio engineer, perhaps, this method is satisfactory.

But for the average radio newcomer, there is a far better way of beginning. Do you remember how you learned to play baseball, or to drive a car, or to do any one of a hundred different things that require a development of skill? Not all the explanations in the world seemed of much use until you had actually tried out these methods yourself. Not until you had the actual conditions of playing baseball or driving a car before you, did you begin to see how different the job really was from what it had sounded like.

Now, in the same way you can learn radio by doing simple but effective practical work, by putting the knowledge you gain to actual use, and by working up gradually to more advanced material. We believe that for radio newcomers this method is by far the best.

By building a simple radio set from a circuit diagram, you will become familiar with basic radio parts and their functions, with set layout and construction. with the meaning of the various radio symbols, and with some of the fundamental notions behind radio design. You will get that feeling of real achievement when you find that the first simple set you have built will actually work. And, finally, you will bring an intelligent understanding to your work when you approach the more difficult phases of radio.

Accordingly, in our discussion, we shall keep uppermost in our minds the needs of the radio newcomer whose first goal is to build a radio set that will work. We shall discuss the tools and materials you will need. We shall find out the most efficient way of putting a radio set together. And we shall nevertheless introduce whatever theoretical knowledge you need as you need it—and when you are ready for it.

WHAT KIND OF SET SHALL I BUILD FIRST?

To answer this question you will have to consider for a moment just what type of radio reception you are most interested in at present.

Receivers generally are divided into two classifications: Broadcast sets and short-wave sets. S.W. sets are designed to cover the broadcast band also. The constructions of two S.W. sets are described later on. These sets employ plug-in coils for changing from one band to another. It is possible on the short waves to pick-up, even with a simple two-tube receiver, broadcasts from all over the world.

If you are interested in listening to standard broadcast programs, you should build a set which has sufficient amplification to operate a loudspeaker. An excellent receiver of this type is the Knight "Ocean Hopper" described on page 26. This set is very versatile, covering both broadcast and S.W. transmissions by means of interchangeable plug-in coils. Two coils are used for the standard broadcast band between 545 and 1575 kilocycles. The set has sufficient amplification for loudspeaker performance on local stations.

THE RADIO SPECTRUM

The table below covers only the major portion of the radio spectrum on which transmitting is done. Above 545 meters, there are a few weather report and time signal stations and some foreign long-wave stations. Below 10 meters, there are Television, FM, Aircraft, Amateur and Police Stations. Special high-frequency receivers are required to tune in these signals.

Kilocycles	Meters	
550 - -	- - 545	BROADCAST BAND— Local stations and chain programs.
1500 - -	- - 200	
1500 - -	- - 200	SHORT WAVE BAND No. 1— Police, amateurs, airplanes. foreign stations. Best reception at night.
5770 - -	- - 52	
5770 - -	- - 52	SHORT WAVE BAND No. 2— Foreign stations, ships-at sea, amateurs, commercial phone. Best reception during daylight.
30,000 - -	- - 10	

The tuning range of Short Wave sets varies according to the range of the coils used. Usually, this range is from about 9.5 to about 217 meters, and is covered by four separate plug-in coils. In this range you can tune in Amateur stations in the United States and other countries, Short Wave police calls, ships-at-sea, airplane calls, commercial radiophone transmission, and foreign Short Wave stations which transmit from Canada, Mexico, South America, Europe, Asia, Africa. and Australia. If your set is sensitive enough, and if such conditions as atmosphere, time-of-day, etc., are favorable, you can tune in stations in foreign countries many thousands of miles away from your home.

Whether you decide to build a Short Wave set or a Broadcast set first depends on which type of reception is of most interest to you. In many sets Broadcast and Shortwave coils are interchangeable. In such instances the tuning ranges desired can be secured by changing coils.

Another point for the beginner to consider is the type of power supply to be used. Now, since everyone living in a large city, or even in many rural areas, has some type of 110 volt current available, the first thought would probably be to build a set to operate right from the 110 volt house current. Keep this in

mind, however: for a beginner, the easiest type of set to wire is a battery-operated receiver.

With this consideration in mind we start the radio builder with the KNIGHT Two-Tube DX'ER (pages 24-25) which is a battery receiver suitable for both Broadcast and S.W. reception. From every standpoint of assembly and operation this set is ideal for the beginner to start with. The Two-Tube DX'ER must be used with headphones because it does not develop sufficient power to operate a loudspeaker.

On pages 26-27 we describe the KNIGHT "AC-DC Ocean Hopper." This set will operate from any 105-125 volt AC or DC power line. With separate sets of plug-in coils it will tune all wave lengths from 16 to 550 meters and, on the more powerful stations, will operate a loudspeaker.

You may be wondering why we did not include simpler circuits such as the crystal or one-tube types. The reason is that these latter, while a bit easier to build, have too many limitations and do not repay the builder, in performance, for his expenditure of time and effort.

While the simplest of all sets is the crystal set, it does not use any tubes and, therefore, cannot amplify a signal. Only the more powerful local broadcast stations can be heard.

One-tube receivers do amplify a signal somewhat, but not enough for completely sastifactory reception. Although many stations in the broadcast band can be picked up, the low volume available from the weaker short-wave stations will result in a strain on your ears and your good nature. The construction of a two-tube set represents very little more time and expense and will provide much finer results. No greater ability is required to build a two-tube set than a one-tube set, and the builder learns something about the fundamentals of amplification.

After you have mastered the technique of radio construction, you should, by all means, build a superheterodyne-type receiver. The many advantages offered by this type of circuit (as explained in detail a little later) make this a *must* in your plans for future radio construction. If you purchase one of the complete kits (such as the *Knight* 5-Tube AC-DC Superhet Kit) you will receive every needed part as well as clear pictorial and schematic diagrams which make construction easy. All modern receivers, whether of the communications or home type, use the superheterodyne circuit in one of its many variations.

TYPES OF CIRCUITS

The chief characteristics to be looked for in any radio set are: *selectivity* (ability to separate stations); *sensitivity* (ability to pick up weak signals); *stability* (ability to stay dependably tuned to a signal); and *fidelity* (ability to reproduce exactly what is put on the air from the transmitter.)

The most selective type of circuit is the *Superheterodyne.* This circuit also provides, in greatest measure, all the desirable characteristics in radio. It is therefor used in most commercially built sets and is considered standard design. Since great *selectivity* is obtained only by sacrificing *fidelity,* care should be exercised to maintain proper balance between these two desirable features.

The *Tuned Radio Frequency* (T.R.F.) circuit is one in which R.F. amplifier circuits are tuned to the desired frequency by varying inductance or capacity. This circuit offers good fidelity, but is less selective than the Superhet.

The *Regenerative* circuit is the third chief type. In such a circuit, in effect, sensitivity is increased by superimposing the amplified variations of the plate circuit on the input circuit. For the purposes of the beginner, the Regenerative circuit is probably the best because it is easiest to wire, most inexpensive insofar as parts are required, and both selective and sensitive enough for ordinary purposes. That is why we recommend the Knight Two-Tube DX'ER as the first set for you to build.

HOW TO READ SCHEMATIC DIAGRAMS

Now, if you have already turned ahead to look at the diagrams in the latter portion of this book, you will have seen that they consist of numerous symbols, lines. circles, and arrows, with occasional labels in words or letters. Let us see why radio circuits must be represented in terms of such symbols.

In the first place, you will agree that some sort of diagram or blueprint is necessary as a basis for construction work. The function of such a diagram is, of course, the same as that of any blueprint used in constructing a desk, a table, a ship model, or a house. You want to know just how every part fits together. You want to have an accurate guide to follow as you work. You want to know exactly what is coming next and where it goes. You want to be sure that when you have completed your job, the finished receiver will be exactly what you set out to build. Hence, a diagram is needed.

The circuits described in detail later on are shown in both pictorial and schematic forms. Pictorial diagrams are the easiest to follow and enable you to quickly determine the proper layout of part. But since pictorial diagrams require a great deal of effort and the skill of an artist to make, they are seldom used. Instead, most magazine construction articles. most radio hand books, and even beginners' manuals employ what are known as *schematic diagrams.*

A schematic diagram is simply a plan or drawing of a radio set in which the various parts and connections are indicated by standard radio symbols.

The symbols used in schematic diagrams are explained in the chart on the next page. These symbols are merely a kind of shorthand in which we use a

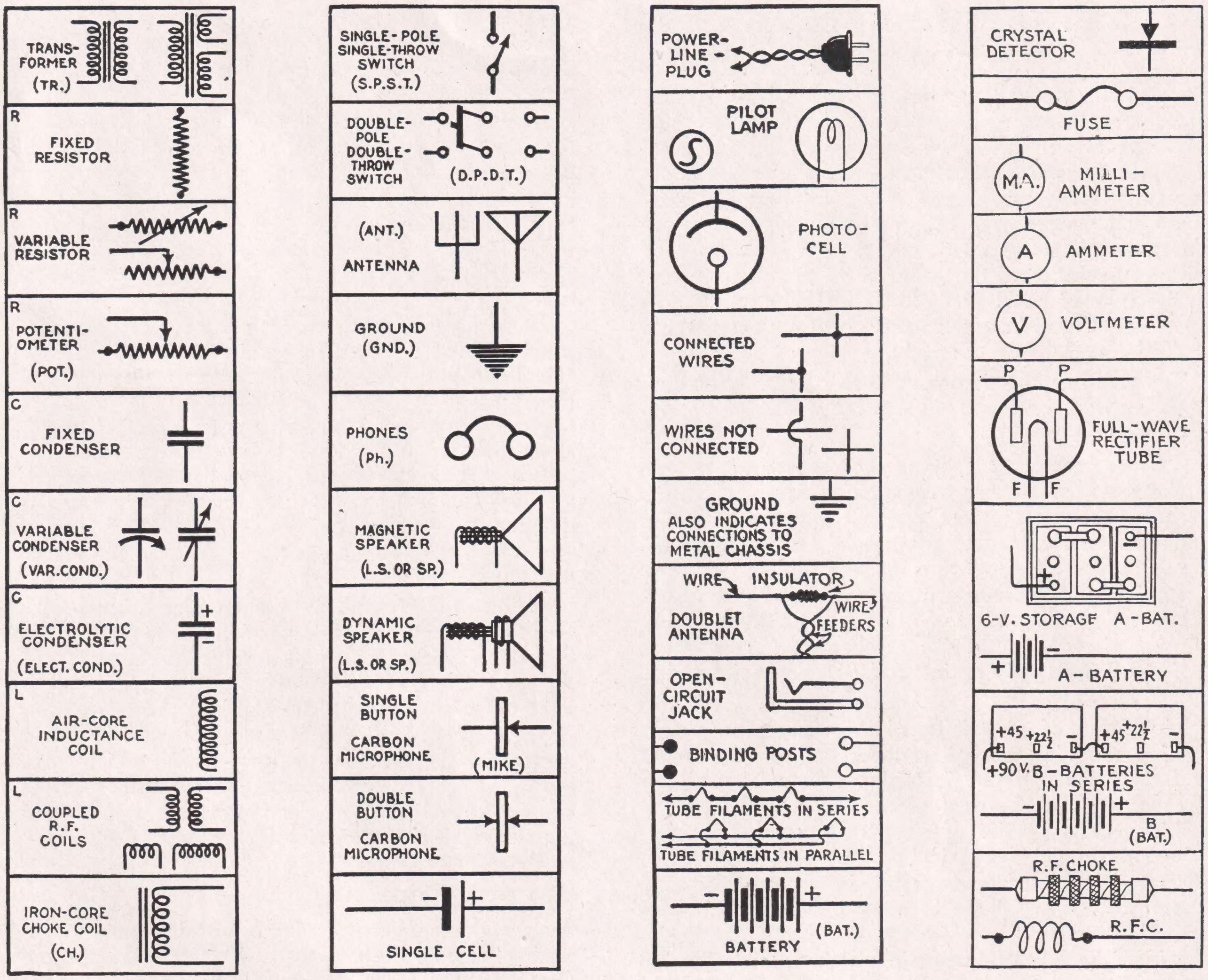
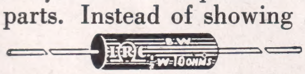
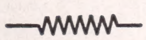
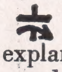


Figure 3. Schematic symbols used in circuit diagrams.
(Furnished through the courtesy of *Popular Mechanics Magazine.*)

standard symbol to represent radio circuit component parts. Instead of showing a picture of a fixed resistor  every time this part is used in a circuit, we employ the corresponding symbol  This symbol always means a fixed resistor. If you will turn ahead to one of the diagrams at the back of this book, you will easily be able to pick out the portions of the circuit in which a fixed resistor is used.

Again, instead of drawing a picture of a condenser we use the symbol  ; or, for a variable condenser  ; and so on. Examine the chart of symbol explanations that is shown above. Once you understand the meanings of the symbols, radio circuit diagrams will no longer seem mysterious to you. You might also refer to your ALLIED catalog to see what the actual items look like. Finally, study several schematic diagrams and identify every one of the parts.

Since you will frequently find it necessary to use symbols in drawing circuits by yourself it is also advisable for you to obtain practice in drawing these symbols as well as in recognizing them. This, of course, is a rather simple procedure since it requires only the ability to copy symbols as shown above. It is suggested that you first learn how to draw the individual symbols—memorizing them as you draw them. After a time, you will find it beneficial to copy an entire diagram so that you can gain proficiency in arranging the elements in a diagram. After sufficient practice, you ought to be able to draw simple diagrams from memory.

It is essential to learn to read schematic radio diagrams in order to be able to make progress in the field of radio. With a little patience and some practice, you will soon be able to recognize all the symbols without difficulty.

SOME THEORETICAL BACKGROUND

At this point we shall take time to discuss, briefly, some of the theoretical considerations which underlie the whole science of radio. We shall not go into too great detail, but we shall describe radio theory to the extent necessary for your purpose as a radio-builder. You could skip over to page 12, go on with the instructions for putting a set together, and get the set to operate without having read the material on these first pages. but you would never really know just why you had to do certain things in constructing your set—you would really be working in the dark.

To begin with, radio and electricity are both branches of the science of *Physics*, which the dictionary defines as:

> The science that treats of the phenomena associated with matter in general, especially its relations to energy, and of the laws governing these phenomena, excluding the special laws and phenomena peculiar to living matter (biology) or to special kinds of matter (chemistry). Physics is generally held to treat of (1) the constitution and properties of matter, (2) mechanics, (3) acoustics, (4) heat, (5) optics, and (6) electricity and magnetism.

The force of electricity plays a leading role in making possible the whole range of radio transmission and reception. In the first place, your home radio depends on the electrical power line or on batteries (which are reservoirs of electrical power) for operating current. This electrical power may be changed in form and increased or decreased in voltage (electrical pressure) before it is made to serve the circuit. In the second place, besides this external electrical energy, the incoming electro-magnetic waves striking the antenna of your radio set up minute but definite electrical currents in the input circuit of the radio receiver.

Electricity itself is a mysterious agent made to serve our needs in many ways. While we are able to control and use this energy quite safely, we really do not know exactly what it is. Over a period of years, however, scientists have been able to devise a useful theory which fits all the facts and is now quite generally accepted.

THE ELECTRON THEORY

Briefly, this theory might be summarized somewhat as follows: All matter in the world is made up of ninety-three fundamental materials called *elements*. These include such familiar elements as oxygen, hydrogen. carbon, gold, etc., and some rare substances known as radium, tungsten, yttrium, helium, etc. A combination of these elements yields other substances; for example, hydrogen and oxygen, combined in proper proportions, result in water. The elements themselves are composed of a number of *atoms*. No one has ever seen an atom, since even the most powerful microscope cannot magnify an atom sufficiently to make it visible.

If an atom could be isolated, however, we should find, according to modern theory, that it is made up of a central body of positively charged electricity consisting of a number of *protons*, surrounding which are bodies of negatively charged electricity called *electrons*. The opposing electrical forces in the proton and electron serve to keep the atom united. Electrons and protons are the same in all atoms. The difference between atoms lies in the number of electrons and protons which make up the atom and in the method of their combination.

Each electron, of course, is very small, and millions upon millions are required to form the current used to heat the filament of a single radio tube.

Electrons exist everywhere in nature and free electrons tend to be present in equal numbers in all places. If a body has more electrons than surrounding bodies it is negatively charged. But if a body lacks sufficient electrons to be neutral, it will be positively charged. Now, if a positively charged body is brought into contact with a negative body, there will be a flow of electrons from the negative to the positive (see Fig. 4) until both bodies will become neutral (that is, both will have an equal number of electrons). In short, electrons, being negative in potential, are always attracted to a positively charged body.

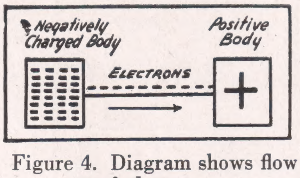


Figure 4. Diagram shows flow of electrons

The charged bodies need not be brought into direct contact for the electrons to flow—a wire which acts as a conductor may be used instead. Practically all metals are good conductors of electricity. Silver is the best, but since it is too expensive for ordinary use, the next best conductor, copper, is widely used.

RESISTANCE

Any conductor, however, has a certain amount of opposing force to the passage of electrons. This opposition is known as *resistance*. Silver or copper wire has very little resistance (which is why copper is so extensively used for carrying electric current). Iron wire. on the other hand, has quite a bit of resistance, and may become hot when many electrons are retarded in their passage. Heavy thick wire—which permits the easy passage of millions of electrons—has less resistance than fine, thin wire of the same material—which slows up the electron flow. (See Fig. 5.)

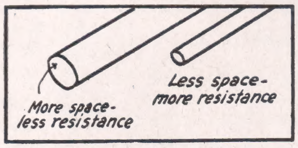


Figure 5. Relation of wire-size to resistance.

Some substances other than metals have extremely high resistance; they permit very few electrons to pass. Some of these substances are rubber, bakelite, glass, and porcelain. Because of their high resistance they are used as *insulators*. There is no such thing as an absolute non-conductor.

The unit of measurement for resistance is the *ohm*.* Assume that we have a battery of one volt connected to

*Named for George Simon Ohm (1789-1854), a pioneer German physicist. Ohm's interest in the phenomena of the relation of resistance to current intensity and electromotive force led to his formulation of the Law named for him and published in 1827.

a wire one ohm resistance. Then an electrical current of one *ampere* will flow. You can see, now, that the voltage, the current, and the resistance of any circuit are interconnected. In Direct Current circuits, this relationship is expressed mathematically according to Ohm's law: $E=I\times R$. In this formula, each symbol stands for one factor: E for voltage, I for current in amperes, and R for resistance in ohms.

THE BATTERY

In the early days of radio, batteries were used as the source of power. Even today in communities not yet reached by power lines, battery-operated radio receivers of the modern type afford facilities for quality reception.

Batteries are simple chemical machines producing electrical current from a chemical reaction. A battery consists of a number of cells, each cell producing a quantity of electricity. The ordinary flashlight cell, for example, produces 1½ volts. In such a battery the zinc can is used as the negative terminal, and the carbon rod in the center of the cell is used as the positive terminal. Inside the cell are a number of chemicals; a chemical reaction takes place each time current is drawn from the battery. The larger "B" batteries are simply composed of a number of these smaller cells connected together.

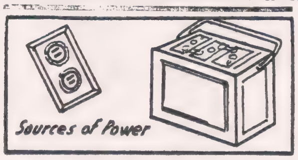


Figure 6. Electric power is obtained from battery or light outlet.

There are two chief types of batteries. One which produces electrical current of itself until it is discharged and must then be discarded uses *primary cells.* This is the familiar dry cell described above. The other, the storage battery used in automobiles and for radio service is known as the *secondary* cell type. It acts as a reservoir of electrical energy. First, the electricity must be "poured" in—that is, the battery must be charged. After the battery has been charged, electricity may be drawn out until the battery becomes discharged, at which time it must be charged again, and so on.

MAGNETISM

Another force closely related to many radio and electrical components is *magnetism.* Transformers, motors, and generators, loudspeakers, relays, and other radio parts, operate on the principle of magnetism. Since magnetism is similar to electricity, we cannot really see it or feel it, but its effect can be detected and accurately measured with simple instruments.

As you already know, a magnet will attract objects made of iron or steel. This is accounted for by the fact that any magnet has two poles of opposite polarity (that is, of opposite force). When two separate magnets are brought together, the like poles will repel each other, while the unlike poles will have a strong attraction for each other. This is the same as the action of electrons and protons. Since the entire earth may be considered as a giant magnet, a compass using a small magnet on a pivot will tend to point to the North and South Poles.

One of the laws of magnetism we might mention is that *the force of attraction and repulsion between two magnets is inversely proportional to the square of the distance.* North and South magnetic poles will attract each other four times as much at a distance of one inch, as at a distance of two inches. When a magnet is dipped into iron filings, most of the filings stick to the poles. indication that the force of attraction is greatest at the poles (Fig. 7.)

Magnetism may also be produced by the flow of electrical current through a conductor. Every wire which carries electric current has an associated magnetic field proportional to the current strength and the placement of the wire. By winding a number of turns of wire in the form of a coil, a much stronger magnetic field can be produced, since the field of each individual turn will add up. And, since the magnetic field of force of each turn is added to that of the next turn, the greater the number of turns of wire, the stronger the magnetic field.

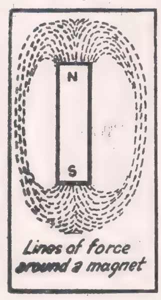


Figure 7.

The total magnetic *flux* (lines of force) depends on the number of turns and the strength of the current. If the current is strong, relatively few turns of thick wire will be required. On the other hand, if the current is weak, a great many turns of thin wire will be needed.

A stronger electromagnet can be made if a bar of iron is placed in the center of a coil, since the lines of force produced will be concentrated and stronger magnetic action will result. In any electromagnet, of course, the magnetism will be lost immediately when the current is shut off, whereas in natural magnets the magnetism is more or less permanent.

INDUCTANCE AND REACTANCE

The property of a coil to set up a magnetic field when current is flowing through it is called *inductance.* Such a coil tends to oppose any changes in current intensity.

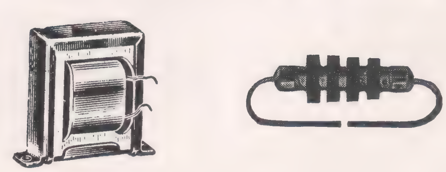


Figure 8. Illustration at left shows an iron-core choke. At right is an air-core choke.

The opposing force of an inductance, known as *reactance,* is directly proportional to the inductance of the coil. The inductance is measured in units called *henries,* while the reactance is measured in *ohms.* (In

*Named for Andre Harie Ampere (1775-1836), distinguished French scientist. Ampere's work in the field of electrodynamics helped to lay the foundation for Edison's work in electricity.

radio work, the *henry** is rather too large, and so the *millihenry* — one thousandth of a henry — and the *microhenry*—one millionth of a henry—are commonly used terms.) The same inductance will have a greater reactance at a higher frequency. This is why an R.F. choke will have a "choking" effect on high radio frequencies, but will permit low frequencies and D.C. (direct current) to pass unobstructed.

So far, in talking of electric current, we have assumed that it is a steady flow of electrons in one direction. However, unlike Direct Current, which is a steady flow in one direction, *Alternating Current* (A.C.) is constantly varying in intensity and in direction. The current and voltage flow, as the name implies, first in one direction and then in the opposite direction. The change in direction does not occur abruptly. In one-half a cycle the voltage and current will rise from zero to a peak value and go down to zero again. Then, without stopping to take a breath, it starts in the opposite direction, rising to a peak value and then decreasing to zero. This completes the *cycle* (Fig. 9). The same variations go on as long as current is flowing. In 60 cycle current, which is now largely standard for power circuits in the United States, these complete cycles take place sixty times each second. In radio circuits the changes (frequency) may take place many thousands or even millions of times per second.

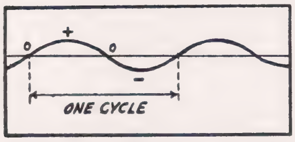


Figure 9. The alternating current cycle.

CAPACITANCE

Two similar metal plates facing each other, but separated by air or by a thin piece of insulation, form what is known as a *condenser.* If such a condenser is connected to a battery, electrons will flow from the plate connected to the positive terminal of the battery, through the battery to the opposite plate. By disconnecting the battery and shorting the condenser, the electrons will pass back through the shorting wire and on to the other plate again. (Fig. 11.)

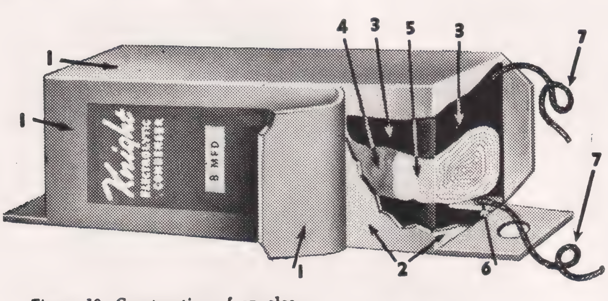


Figure 10. Construction of an electrolytic condenser.
1. Cardboard container.
2. Inner liner.
3. Wax.
4. Aluminum foil.
5. Cellulose separator.
6. Sturdy connection.
7. Leads.

*Named after Joseph Henry (1797-1878), one of America's pioneers in the science of Physics. Henry was especially interested in electromagnetism, but also made important contributions in other fields.

Capacitance (storage ability) of a condenser depends on three factors: (1) size of plates, (2) spacing of plates, and (3) the dielectric used. The larger the plate area, of course, the greater the capacity.

The unit of measurement is the *farad**. However, one farad of capacity is a much higher value than is ever used commercially; therefore, the microfarad (millionth of a farad) or the micro-microfarad (millionth of a microfarad) is used. These are abbreviated mfd. and mmfd.

The term *capacity* is now quite generally used as meaning exactly the same thing as *capacitance.* Strictly speaking, *capacitance,* according to some experts, should be used only to refer to the electrostatic capacity of a body, and *capacity* should be used to refer only to current carrying ability. However, in general usage, these terms have been confused and are now taken by many to be synonymous. Accordingly, we have used the term *capacitance* above rather loosely. You need not worry about this matter, however, since only the expert radio engineer or theoretician will be very critical of your usage of these terms.

Different dielectrics give different total capacities, even though the plates and spacing are not altered in any way. If a condenser has a given capacity with air as the dielectric, it will have seven times the capacity with mica substituted as the dielectric. The *dielectric contant* of air is taken as 1, of mica as 7; other substances have their corresponding dielectric constants.

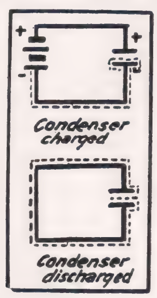


Figure 11.

Condensers not only store up energy, but are also important in radio work for another reason. If a condenser is connected in a circuit with direct current being supplied, the condenser permits the current to flow only for a very short time while it is being charged. If alternating current (see above) is supplied, the condenser will permit the current to flow through the circuit. Thus a condenser which permits A.C. to flow, but does not allow D.C. to pass through, is called a *blocking condenser;* one which permits A.C. to pass through a shorter path than D.C. would follow is called a *by-pass* condenser.

In many radio condensers waxed paper or mica is used as the dielectric. Those circuits in which D.C. or pulsating D.C. is present may use *electrolytic* condensers, in which an extremely *thin* film forms on one of the plates and serves as the dielectric. Since this film is so thin it permits high capacity condensers to be constructed very compactly. The cutaway illustration at left shows clearly the construction of an electrolytic condenser. The aluminum foil represents the plates.

The chemical nature of electrolytic condensers adapts them particularly to use in power supply circuits using up to 450 volts D.C. only.

*From the name of Michael Faraday (1791-1867), an English scientist who made many notable contributions in chemistry and in physics. Also a pioneer in electricity.

THE PARTS OF A RADIO SET AND THEIR FUNCTIONS

In the simplest language, *a radio receiver is nothing more than a device to capture radio signals which travel through space and to reproduce them as audible sound.*

These radio signals, of course, are emitted by the transmitter where the process is just the reverse of that in a radio receiver. In other words, a transmitter converts audible sound into radio signals and radiates these signals through space.

Now, how are these signals which we cannot see or hear or feel captured by the radio set and transformed from mere electrical impulses into the voice of Bing Crosby or Rudy Vallee or the music of the Philadelphia Symphony Orchestra?

This is a good place in which to explain the functions of the various radio parts so that when you come to a later section in which we tell you how to construct a set, you will understand why a great variety of parts is needed and what these parts do.

Broadly speaking, any radio receiving set has five chief sections—all concerned with turning those invisible, intangible radio signals into sound that you can hear. These sections are:

1—The antenna
2—The Radio Frequency Amplifier (if used)
3—The convertor (or detector)
4—The Audio Frequency amplifier (if used)
5—The Loudspeaker or Headphones.

And what, you will ask, are all these for?

Well, in the first place, the antenna—which is a piece of wire, either long or short, and either indoors or outdoors—captures the radio signals which are dashing through space at the approximate speed of 186,000 miles per second. (The great speed explains why radio signals can be sent around the world and heard almost simultaneously whether you are in Singapore, or Copenhagen, or New York City, or San Francisco, or Sydney, Australia.) As a matter of fact, if you were to dangle a piece of wire out your window you would have the rudiment of a radio set because you would receive signals—although there would be no apparent result because you would lack the necessary conversion device.

Now, the Radio Frequency amplifier (practically always a tube in conjunction with one or two tuned circuits) amplifies the very weak signals which have been received so that they are strong enough to be passed on through the rest of the circuit. Incidentally, the term *Radio Frequency* is used to indicate the frequencies above 40,000 cycles per second which are not audible to the human ear.

From the Radio Frequency amplifier (commonly abbreviated as R.F. amplifier), the radio signals go through the converter or detector stage which, very roughly speaking, serves to break up the incoming signal so that only the Audio Frequency component is left. This function is also performed by a tube.

Next is the Audio Frequency amplifier (or A.F. amplifier) which increases the strength of the A.F. signal.

The final stage is that in which this strengthened A.F. signal is converted by a loudspeaker or headphones into audible sound.

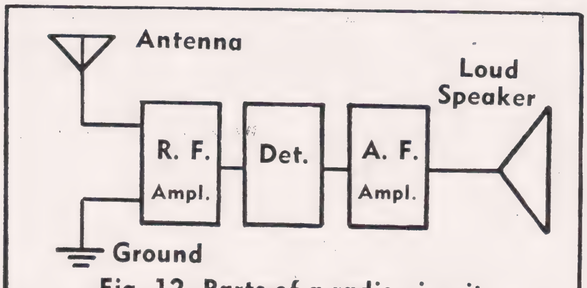


Fig. 12. Parts of a radio circuit

Actually, this whole process we have described takes place in a period of time so short that it can scarcely be measured. Practically speaking, the sound of the program you hear leaves the loudspeaker at almost the same instant it has entered the antenna as radio signals.

In order to operate the tubes used in a radio set, it is necessary to employ some form of electrical current, whether it be from batteries or from a regular electric outlet in the wall. If you live in a city, you probably have 110 volts 60 cycles Alternating Current. Since the tubes used in a radio set require direct-current power to make them operate, it is necessary to transform and convert the incoming voltage to the proper type and voltage needed for the tubes. This is the function of the *transformer,* the *rectifier* and of the *filter network* in the set.

Condensers and coils, when used together, comprise what we call the *tuned circuits.* When adjusted by the knob controlling the condenser to the frequency or wave length of the station wanted, the tuned circuit passes signals from that desired station to the tubes, from which point the process goes on as we have already described it above.

As for the remaining parts in a set, we may say that a rheostat is a type of variable resistor used to increase or decrease the amount of current flowing in the circuit; a potentiometer is another type of variable resister which is generally used as a volume control. A choke is a fixed inductance (see page 9) employed to prevent the passing of either audio frequency or radio frequency voltages, depending upon the type of choke used. *Sockets* are necessary to hold tubes or coils in place and to permit correct wiring connections to be made to the various parts of the tubes or coils. A *chassis base* is needed to provide a foundation for the parts in the set. The *dial* is required so that we can revolve the tuning condenser and locate stations at a definite point on the dial scale. Wire and hardware, including screws, cords, clips, plugs, etc., are needed to make the connections between the various parts of the circuit and to hold all parts rigidly in place.

By now we have said practically everything that the beginner needs to know about the various radio parts. Something more must be told about tubes—their various types and their functions—but we shall reserve that for a later section.

THE TOOLS NEEDED FOR RADIO CONSTRUCTION

In order to assemble the various parts of a radio set, you will require a number of simple, inexpensive tools. No doubt you already have some of these tools somewhere about your home.

Practically all the radio work encountered by a beginner can be taken care of with these tools:

- 1 soldering iron
- 1 pair of long-nose pliers
- 1 pair of diagonal cutters
- 1 screwdriver (5″ or 6″ size)
- 1 screwdriver (2″ or 3″ size)
- 1 drill kit, consisting of hand drill and assorted drills such as Nos. 11, 18 and 27
- 1 center punch
- 1 circle cutter
- 1 hammer
- 1 steel rule (12″ size)

Optional Tools

- 1 vise (4″ size)
- 1 hacksaw
- 1 square
- 1 file (medium coarseness)

With a little practice you can soon acquire a certain dexterity in using your tools so that your work will always be neat and shipshape. There is no special knowledge required for using most of the tools mentioned above. The soldering iron, however, calls for a little extra skill and so we have devoted a separate place to a discussion of this tool.

As a matter of fact, you can assemble many radio sets (for example, the Knight kits shown in the section beginning on page 24) with exactly three tools: screwdriver, soldering iron, and pliers. This is because special care has been taken to supply such kits in a form which will require the minimum of work and ingenuity on the part of the radio builder.

However, since punched and drilled chassis are not always available as, for instance, in the construction of most circuits described in the various radio magazines, the three essential tools will not be enough. You will need to make use of most or all of the tools listed above.

It is also advisable to get in the habit of keeping your work-table as efficiently organized as possible. Many radio builders, it is true, manage to get all of their set-building done in a more or less haphazard fashion, using the kitchen table as a workbench. The ideal set-up however, is to have a place of your own—small as it may be—in which to handle your radio work. A table in your bedroom, a bench out in the garage, or in your basement, are examples of what we mean. Try to get into the habit of keeping tools and parts stored in definite places. A small cabinet with a number of drawers is an excellent place to keep small parts such as hardware, extra condensers, tubes, and so on. Tools may be kept in a drawer of your workbench (if the bench is so equipped) or any other place where you will find them at hand when you need them.

One final point on this subject: make sure that you have all the parts or tools you need when you begin to work. If you purchase a complete kit of parts you will have every part necessary to build your set. However, if you are building up a special circuit, you will find it most annoying to have to stop in the middle of your work because a couple of screws or some hook-up wire, or a resistor or two are not available when you need them. Also: never throw anything away. So many times an odd piece of equipment for which you have no use will come in handy at some later time.

SOLDERING

In the construction of any radio set, wire connections to sockets, coils, or to other wires are made by means of soldering. The purpose of soldering is to provide connections which are firm and secure both mechanically and electrically.

You must not depend on soldering alone, however, to provide the correct connections. It is always necessary to wrap the wire around the terminals *first* and then to apply the solder to seal the connections.

Successful soldering depends on your following a few simple but important instructions. Always hold the heated iron to the joint (point of connection) until it becomes hot enough so that the solder, when applied, will melt when it comes in contact with the joint. When the solder on the joint is melting, the iron must be removed at once. Your connection will then be secure and foolproof.

A soldering iron is easy to care for, and, when properly used, will last for a long time. Always keep the tip of the iron clean and well tinned. This tip is made of copper and, when in good condition, will either be clean and shiny or covered with solder. If, however, the tip gets black and rusty, the copper is being oxidized, and cleaning is necessary. To clean the iron, secure what is called a "tinning block", which consists of a solid block of material soap-like in appearance. Heat the iron and then rub it across the surface of the block several times, until the tip is perfectly clean.

Lacking a tinning block, you can keep your iron fairly clean by wiping it across a piece of heavy cloth or felt fastened down on your work bench.

Several types of solder are commercially available. In general, the radio builder should use solder which has a core of rosin flux inside of it so that soldered connections will be made permanent. *Acid core* solder should be used for all sheet metal work. *Rosin core* solder is best for radio connections, such as are made in wiring a circuit. *Aluminum core* solder must be used when aluminum is to be soldered.

Caution: In using solder, take care to use only as much as is necessary to cover the joint. If too much solder is used, and if it spreads over nearby insulation the results will be either breakdown of the insulation or excessive electrical leakage between adjacent terminals.

GETTING THE RIGHT CHASSIS BASE

If you will look into the cabinet of your home radio set you will notice that all of the tubes and other parts are mounted on a metal base, usually about two or three inches in height. This is known as the *chassis base*, because the assembled radio set, exclusive of the cabinet, is called a *chassis*, and this metal piece provides a foundation or base for the chassis.

For simplicity and ease in circuit wiring and in making changes, many experimenters prefer to use a wood base. A base board of proper size and with smooth finish is supplied as a part of one of the kits included in the latter portion of this book. Of course, you can prepare your own base, if you wish. A piece of wood about a half inch thick sandpapered to a smooth finish and stained to a dark shade, is all that is needed. In the so-called "breadboard" style of layout—as used, for example, in the Knight Two Tube DX'ER—all parts are mounted on the surface of the board with wood screws and no drilling or punching of the base is necessary.

To improve the operation of the set and to give it a professional appearance, a metal chassis base is used (Fig. 13). All commercially built radio sets use a base of this type. Several different metals are available. The most popular is *electralloy*, a soft, easily worked material that can be soldered with ordinary flux. *Ternplate* is a steel alloy material, lower in price than electralloy, but considerably more difficult to handle.

Both the chassis bases and the matching front panels are usually furnished with a polished natural finish. Black crackle-finished metal is also available.

HOW TO PUNCH AND DRILL CHASSIS BASES

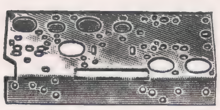


Figure 13. Typical punched and drilled chassis base.

If you use the proper tools you will find that the chassis bases can be rapidly prepared for mounting the necessary radio parts. These tools are low priced and are designed especially to permit ease in use.

Follow these valuable suggestions, and you will be able to make your own chassis base easily and conveniently.

The first step is to determine what size chassis base will be needed. If the construction article or parts list from which you are working does not tell you this, it is advisable to lay out the parts to be used in the set on a table and experiment with placing until you have a neat layout permitting short leads and estimate what size the surface of the base must be. It is necessary to remember, also, that the chassis base is not merely a flat piece of metal when finished, but has a height at the sides of from two to three inches. Accordingly, in figuring your dimensions, allow for these sides.

Assume, for example, that you will require a chassis base measuring about 7″ x 10″ x 2″. You must then obtain a piece of metal that is at least 11½″ x 14½″. Then follow this procedure:

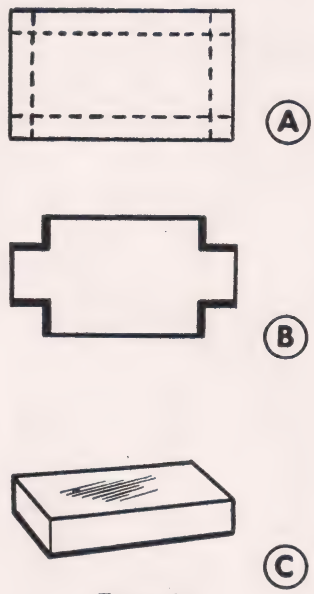


Figure 14.

Measure out guide lines about 2¼″ along four sides of the metal. From these guide lines, plot out the lines for the surface, which will be 7″ x 10″. Be sure to allow about ¼″ where the sides will be, so that in folding the sides you will secure a neat, squared-up finish. (Fig. A.)

Cut out a square notch about 2¼″ at each of the four corners, so that the side pieces can then be folded under. (Fig. B.)

Fold these sides and your finished base will appear much like that shown in Figure C.

To cut sheet metal to proper size, scratch guide lines for cutting with a nail or sharp-pointed tool. Then, using a hacksaw, cut off the metal along the guide lines. Use a file to remove rough edges. And, finally, to finish the edges smoothly, use a piece of sandpaper or emery cloth attached to a flat surface and rub the edges down until they are perfectly smooth and straight.

To cut aluminum or alloy, the best method is this: Make deep scratches along the line of the cut on both surfaces of the metal. Place the metal in a vise, bend it back and forth, and it will soon break at the line. In the event that the metal to be cut is much wider than the vise, insert a pair of iron bars, one placed on each side of the metal, tighten the vise, and then proceed as above to break the metal.

Whenever holes are to be drilled in metal, always use a center punch first to locate the exact center of the hole. A valuable guide in this job is a heavy sheet of paper on which an outline of the exact placing of the components has been plainly traced. This sketch may easily be fastened to the metal chassis by using gummed paper or adhesive tape. The holes may then be punched through the paper and you will thus avoid marring or scratching the metal surface.

Some care should be taken to get the measurements of the holes as accurate as possible. If the holes are too large, the parts will not fit properly; if the holes are too small, you will need to spend some time in filing them down before they are the proper size.

To cut out the holes you can use either a drill or a hole-punch. Holes smaller than $\frac{3}{16}$ of an inch can easily be made with a drill. Larger holes should first be made with a small drill, after which larger drills

are used to enlarge the hole until the proper size is reached. A circle-cutter or a radio chassis punch is also useful for this work. These tools are not expensive and, if you do a great deal of work of this type, will easily be worth their cost.

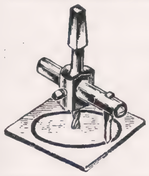


Figure 15. A circle cutter is handy for cutting round holes from ⅝ inches up to 8 inches.

When all holes have been drilled, file or ream off the burrs. You can also give your panels and chassis a professional appearance by painting them with one of the air-drying crackle varnishes or lacquers which are now available in many popular colors.

MOUNTING THE PARTS

One aspect of radio building which sometimes puzzles beginners unduly is that of actually mounting the parts on the chassis base. To clear up any vagueness you may have on this subject, we shall talk about this problem now.

In the first place, the chief idea to keep in mind when mounting parts on a chassis is this: Always arrange the layout so that all leads will be as short and direct as possible. *Above all, the grid and plate leads must be very short.* The reason for this is to assure best operating results, because long leads will result in excessive coupling and stray pickup, which may prevent the set from performing as it should.

Another point to remember is this: When placing parts tentatively for mounting, see that all controls are at the front panel. For example, the tuning condenser and its associated dial should be mounted so that stations can be tuned from the front panel. In the same way the volume control, tone control (if any) and other controls such as a rheostat or potentiometer should always be placed so that the control shaft will protrude from the front panel. You can easily see why this is necessary—otherwise, you would have a good deal of inconvenience in operating the receiver.

If the set you are building is described in a magazine construction article, you will usually find an illustration showing how the parts are laid out. It is best to follow such a layout because the author of the article has undoubtedly spent some time in experimentation to assure best results. If you are working from a diagram of the pictorial type, you will also be given definite clues as to how parts should be laid out. But remember—*always try for the shortest possible leads.*

In your first tentative layout of parts, you may find that better wiring facilities can be obtained by changing the position of two or three parts. Accordingly, juggle the parts around until you are sure you have the best possible plan. Then, but not before, go ahead with the final drilling.

Place all mounted parts such as sockets, upright condensers, transformers, etc., on the chassis in accordance with the holes you have previously drilled. Set in any screws or terminals which hold these parts in place. After all these parts are mounted, you can proceed with wiring.

Another hint to keep in mind is this: always wire the filament and power supply portion of the set first. When this unit has been wired according to the circuit diagram, test it by plugging in the line cord (if it is an A.C. or A.C.-D.C. receiver) or by attaching batteries (in case of a battery set). If the tubes light, you will know that the wiring is correct up to this point at least and you can go ahead with your work. If the circuit uses metal tubes, you cannot tell whether or not they are working except by touching the tubes to determine whether they are heating up. In a few moments after the power supply is connected, the metal tubes will begin to feel warm to the touch.

Now, if by any chance the tubes do not light up, you will know definitely that you have not followed your diagram exactly. Disconnect the power supply or batteries. Go back and check over the wiring very carefully, noticing at every point whether you have done exactly as the diagram indicates. In this way you can soon discover whether you have made an error and you can quickly correct it.

After the filament and power supply have been correctly mounted and tested, disconnect the power supply (pull out the line cord or disconnect batteries) and go ahead with the remainder of the circuit.

If your set is being constructed on the "broadboard" layout plan, all of the wiring will be on the top surface of the wood base. However, if you are using a metal chassis base, the wiring will be done on the under surface of the chassis. In this latter type of job, you must turn the chassis upside down, so you can get at the terminals from the under side. When such set is completely wired, you will find that the upper surface will be very shipshape—the only apparent parts will be such upright units as tuning condenser, tubes, transformer, controls, etc. All—wiring in most cases—will be underneath the chassis.

Another point to remember in order to make the construction work a little easier is this: As you proceed with the layout of parts and the wiring, use a colored pencil to check off on the diagram each step that you have finished. Unless you do this, you may find that you have omitted some essential bit of wiring and your set will not work. *Every part and wire indicated on a circuit diagram is essential* if the set is to operate correctly. Make it a habit to check your work as you go along. This will save time in the long run and will assure you of best performance from your radio set.

When you have at last finished mounting all parts, connected all leads, and checked your work, you are ready for the final test. Plug into the electrical outlet (or connect batteries if a battery set), turn on the switch, allow the tubes a few moments to heat up, and then operate the tuning control until you hear a station. If your work has been satisfactory, you will

experience quite a thrill in listening to your first program coming in on a set you have built yourself.

THE ANTENNA AND THE GROUND

To obtain the best results from any radio set—whether a crystal set with earphones or an eight-tube superhet with loudspeaker—you must have a satisfactory antenna and ground connection.

It is impossible to state categorically just what type of antenna is best. To determine which is best for any specific installation, you must consider such variable factors as the sensitivity, selectivity, and power of the radio receiver itself; the distance from the nearest broadcasting stations; the number of stations within the local area; the kinds and intensity of interfering devices such as electric flashing signs, trolley car lines, power lines; the physical conditions which limit space for antenna installation, and so on. We can say, however, that in general, for the smaller home-built sets in which good broadcast band reception is the goal, a suitable antenna is a single wire about 50 feet long, installed as high off the ground as possible. That figure—50 feet—should not be taken too literally. We suggest it only because it is about the correct length for a good many installations. If it is found that too many stations interfere and prevent good reception when a 50-foot antenna is used, it is advisable to shorten the antenna. On the other hand, after some experimentation, it may be found that a longer antenna offers better reception. So we say, the length of the antenna required for best reception can be determined only by "trial-and-error" methods.

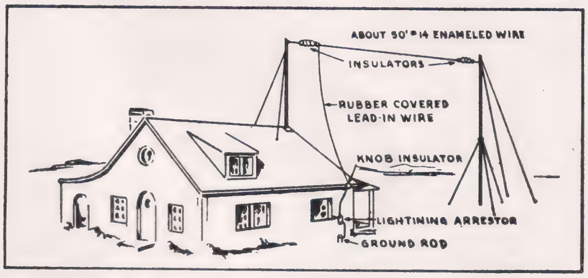


Figure 16

The ordinary antenna for the beginners' sets may be a length of No. 14 or No. 12 (B. and S. gauge) enameled copper wire. The *lead-in* (the wire connecting the antenna to the radio receiver) should be a rubber-covered wire. The rubber covering prevents any possibility of grounding if the lead-in comes in contact with a foreign surface. All contacts should be solid and secure. Loose contacts at lead-in or joint may cause intermittent reception because of signal leakage. Solder the lead-in securely to one end of the antenna, and drop it down directly to the receiver where connection is to be made.

There are a number of points concerning which some specific cautions may be advisable:

1—Since the antenna is exposed to the elements, your installation should be strong and secure so that the first high wind which comes along does not blow the wires down. Poles affixed to buildings should be carefully set up and securely nailed or bolted.

2—Not too much sway of antenna and lead-in wires should be permitted. If the antenna is installed during warm weather, however, allow enough slack so that cold weather will not contract the wires so much that they will snap.

3—Try to prevent aerial or lead-in from touching anything: tree, building, etc. Such contacts cause signal leakage which will result in reduced volume.

4—If there is a high-power line or similar source of interference near your house, point the antenna *toward* the source of interference, to minimize undesirable effects. Never install an antenna parallel to a high-power line if you want quiet reception from your radio.

For advanced circuits of the superhet type—especially for all-wave receivers—a doublet type antenna should be used. Since a good deal of theoretical knowledge is required for construction of an efficient antenna of this type, and since excellent doublet antennas are commercially available at very reasonable prices, you will probably find it better policy to purchase a factory-assembled doublet antenna, rather than attempt to construct your own.

Something too, should be said about *insulators* which are needed for a good antenna installation. Ordinary insulators prevent dissipation of signal strength, and other insulators of the lightning arrester type are used to prevent lightning bolts which may strike the antenna from entering the radio set itself. There are several types of insulators, the best of which are of glass or glazed porcelain. One insulator should be used at each end of the antenna, and another (of the porcelain nail-knob type) should be used at the window where lead-in enters your house.

We have said the antenna should be installed as high off the ground as possible; a minimum of twenty or thirty feet is usually satisfactory. In the city this is easily done by installing the aerial on the roof of your building. In rural areas, one end may be strung from the roof of your house, and the other from a barn or outlying structure, or a pole.

Indoor aerials, in general, should not be used unless physical conditions are such that the alternatives are either an indoor aerial or else none at all. Indoor aerials can never be as efficient as outdoor aerials and at their best are only a compromise. "Aerial eliminators" are not particularly useful if long distance reception is one of your aims, although they are frequently suitable for local-area reception.

A good *ground connection* is almost as important as the antenna for good DX reception. Its purpose is to form the second plate of a condenser, the antenna acting as the first plate. The condenser is part of the open oscillatory circuit in which the signals flow. The ground wire makes the connection between the "Ground" post of your set and a metal pipe or rod, which is driven into or connected with the earth. Use a ground clamp

which will assure a good. solid connection. Suitable grounds are: a radiator pipe, a water pipe, or a rod of iron driven into the earth. The ground clamp should touch bare metal; paint or gilt should be scraped off of the pipe used for a ground at the point where the contact with the clamp is made.

To conclude, we might mention the fact that people may tell you of the "marvelous" reception they got without using an aerial at all. That may be—but for *consistently* good reception, you cannot dispense with an aerial.

NOTE: Receivers of the A.C.-D.C. type—that is, sets which are designed to operate from either Alternating or Direct Current rated at 110 or 220 volts—do not have a power transformer in the circuit. Voltages from the power line are obtained directly. Accordingly, no ground connection should be used with an A.C.-D.C. receiver unless called for by circuit.

RADIO TUBES: SOME BASIC INFORMATION

Vacuum tubes are actually the heart of modern radio sets. While reception is possible without the use of tubes (for example, in a crystal set), such reception is indeed limited both in selectivity, sensitivity, and power. Accordingly, all sets designed or built today use a number of vacuum tubes. The number of tubes employed may vary from one tube—in a simple beginner's set—to 20 or 30 tubes—in custom built sets for special purposes.

Ordinarily, a radio receiving tube consists simply of two or more electrodes within an evacuated glass or metal shell (Fig. 17). This glass or metal envelope is needed to maintain the vacuum inside the tube. The vacuum itself is necessary so that the electrical reaction in the tube can be regulated according to certain specified requirements and so that filaments will not burn out. Only in a vacuum can the flow of *electrons* to one or more of the electrodes be regulated.

As we have already explained (page 8), electrons, essentially, are tiny invisible charges of negative electricity which are capable of traveling at a speed of thousands of miles per second. These electrons make modern tubes possible. Without the constant, regulated flow of these tiny bits of electricity, a tube could not be operated.

Tubes contain several components. The *cathode* is the element in the tube which supplies the electrons. A *directly heated cathode* consists of nickel alloy wire coated with a special substance which gives off electrons when heated. The necessary heat is furnished by passing an electric current through the filament wire. (This is one reason for the fact that some kind of electric current—whether from batteries or from an electric outlet—is required to operate any radio set which employs radio tubes.) Examples of directly heated cathode tubes are these types: 30, 31, 1H5G and 1N5G—all for operation from batteries; and these types: 2A3 and 45—for A.C. operation.

An *indirect or "heater" cathode* tube has a heater or filament inside a metal sleeve. This sleeve is coated with a special substance which emits the electrons. Most present-day A.C. operated tubes have heater cathodes.

A *diode* is a two-element tube with a cathode to supply the electrons and a *plate* to attract and receive the flow of electrons. This plate has a positive voltage applied to it. (Remember that, as we said above, electrons are negative charges; you can see, then, why the plate, which is charged positively, will attract these electrons.) Types 80, 5Z3, and 12Z3 are examples of rectifier diode tubes. Diodes are used most frequently as rectifiers in power supplies or as special detectors.

In order to control the flow of electrons most efficiently, Dr. DeForrest (the inventor of the triode vacuum tube) introduced a control element called the *grid*. This was the beginning of the triode radio tube which has permitted highly efficient methods of transmissions, detection, and amplification of radio signals. The grid is a wire mesh extending the length of the cathode and placed close to the cathode in order to affect the flow of electrons. Commonly used triodes are such types as the 56, 45, and 30.

A small changing voltage on the grid varies the plate current by a larger amount and thereby permits amplification. Thus radio signals which are weak in intensity can be amplified until they are as strong or stronger than the original signals.

The three elements in the triode, grid, plate, and cathode, have existing capacities among themselves which are detrimental to perfect operation. The capacity between grid and plate in a triode limits the possible gain (or increase in amplification).

Accordingly, while a triode represents an advance over the diode tube, a still greater advantage was made possible with the invention of the *tetrode*. (The names given to these tubes can easily be explained when you remember that *diode* means two elements; *triode* means three elements; *tetrode* means four elements and *pentode* means five elements.)

A *tetrode* is similar to a triode but has an additional screen grid to eliminate the undesirable inter-electrode capacity which is found in triode tubes. This screen is mounted between the grid and the plate, connected to a positive potential, and by-passed to ground. Representative types of tetrodes are the 24 and 35.

A phenomenom known as secondary emission—the only limitation of the tetrode tube—is eliminated by the suppressor placed between the plate and screen grid in the more recent *pentode* types. Ordinarily, this suppressor is connected to the center tap of the filament or cathode (as in types 47 and 6F6) or is brought out externally in some types such as 57, 6K7 and 12SJ7-GT.

Until about 1935 radio tubes were manufactured with glass shells. This was due partly because of the fact that the manufacturers of early tubes drew on the experience of the makers of electric lighting bulbs, and partly because it was felt that glass was the most efficient substance for this purpose. In the year mentioned, however, after several years of preliminary research, the so-called metal tubes were first introduced

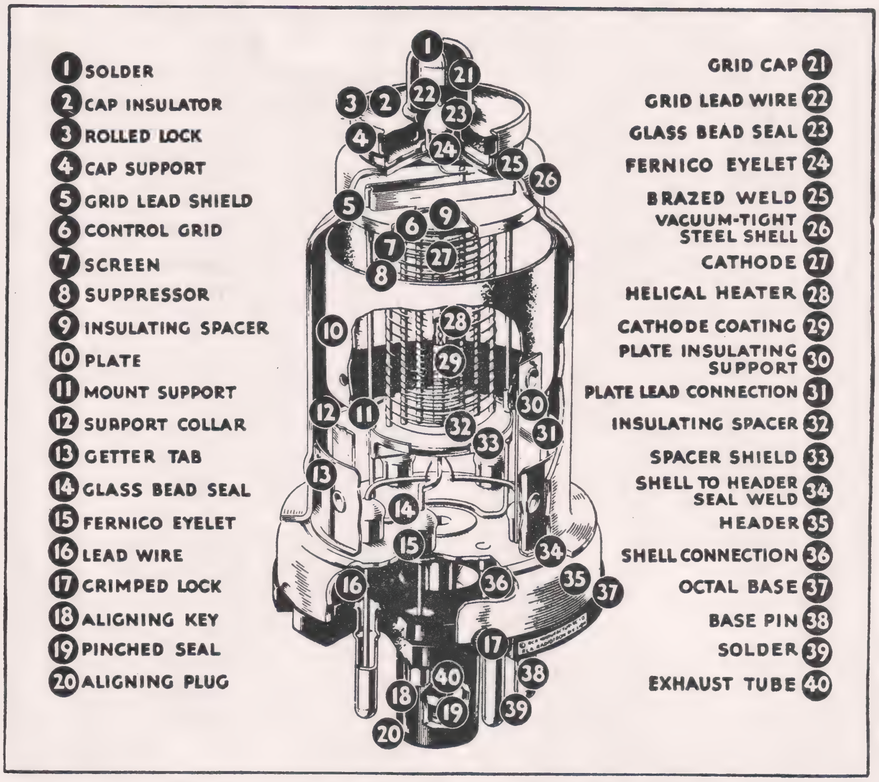


Figure 17. Cross-section of a typical RCA Metal Tube.
This diagram illustrates in detail the construction of a modern radio tube. All elements are clearly indicated. The complexity of the modern tube is here readily apparent. A good basic understanding of tube design and function is essential to good radio building.

on a large scale. These tubes employ a special steel shell which tends, in general, to reduce the hazard of breakage, and to provide somewhat better operation because of the elimination of all stray R.F. pick-up. Metal tubes which have octal (8-prong) bases are interchangeable with glass tubes of the same type.

For the purposes of the beginner this information on tubes is sufficient. However, as you advance in your radio work you will want to know more about tube theory and function; you can acquire this advanced knowledge from any one of a dozen tube manuals or radio theory books (see page 22).

The various tube manufacturers make available without charge, characteristic tube charts which set forth the average characteristics of all types of tubes under a given set of applied voltages. These charts show the recommended grid and plate voltages and in practice may be deviated from within wide limits without affecting the normal operation of a tube. Filament voltages as shown by the charts are maximum values, however, and cannot be exceeded without seriously shortening the life of the tube or even causing a failure of the filament through burn-out.

This tube chart deserves a good deal of study. It will tell you practically anything you may want to know about the performance of any specific tube type. While some of the information contained in the chart may seem of limited use to you just now, eventually, you will find it to be one of the most important pieces of literature in your radio library.

COILS AND COIL WINDING

We have previously mentioned the fact that *coils* are used in the tuned circuit or circuits of a radio receiver. but we have said nothing about these coils. Essentially, they are used to permit reception of radio signals on specific frequencies as desired. For example, a set of Short-Wave coils is required to cover Short-Wave frequencies, and Broadcast coils are needed to cover the Broadcast band.

As we have already stated, a magnetic field is set up around a coil of wire through which current is flowing. This field follows in intensity the strength of the exciting current. The number of turns of wire on a coil determines the portion of the radio spectrum which can be covered with a given tuning condenser.

Coils are wound with magnet wire on forms usually made of bakelite or similar composition material. For convenience in changing bands, some coil forms have prongs at the base such as radio tubes have. Thus, to change bands, you remove one coil from its socket and replace it with another coil that covers the required band.

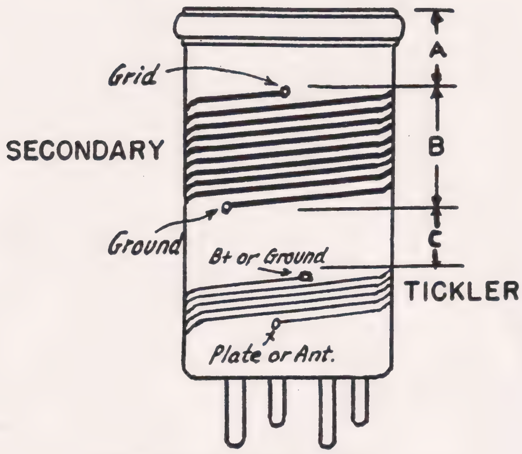


Figure 18. Method of winding a coil.

The chart below contains complete coil data for winding standard 4-prong plug-in coils to cover all Short-Wave and Broadcast bands. P. E. means plain enameled wire; D. S. C. means double silk covered wire. Any round or ribbed coil forms may be used: dimensions should be 1⅜" diameter by 2¼" height.

In winding coils care should be taken to do all winding in the same direction—that is, either clockwise or counter-clockwise. In beginning, drill a tiny hole in the coil form below and parallel to the top edge (see Fig. 18 above). Pass one end of the wire through this hole, down through the coil form, and through one of the prongs at the base. (Your circuit diagram or coil instructions will tell you which prong is to be used in any specific case.) When the bare wire protrudes through the hole in the bottom of the prong, solder the wire to the prong.

Now, proceed to wind the other end of the wire around the coil form for the number of turns specified for any particular coil. When the correct number of turns is made, cut off the wire—allowing about three or four extra inches, pass the end of the wire through another hole drilled at the end of the winding, and proceed to pass it through another prong and solder it as described before.

You have now finished the secondary winding (when using four-prong coils, the tickler winding is connected to two prongs, and the secondary winding to the other two prongs). You can proceed now with the tickler winding, in the same general way as described above. except that the first hole in the form will be drilled about midway down the coil form at the point where the tickler winding is to begin.

When the proper number of turns and windings have been completed, it is advisable to apply a coat of "coil dope"—a special kind of lacquer. This serves two purposes: It holds the windings firmly in place: and it prevents absorption of moisture which might disturb the distributed capacity of the coil and thus affect the tuning range the coil is to cover.

In general, a good deal of time can be saved by purchasing ready-wound coils or a complete coil kit usually offered with construction kits. However, it is suggested that the beginner take the time to wind the coils for some of the sets he builds so that he will understand exactly how the coils are made.

RADIO OPERATING HINTS

Tuning a Short-Wave set or an All-Wave set that covers the Short-Wave bands requires a procedure different from that of simply twirling the dial for Broadcast reception. In the first place, it is necessary to keep in mind such factors as time difference between your own region and foreign countries, atmospheric conditions. and time of transmission schedules. It is advisable to consult a Short-Wave Time Table—included in most good radio magazines or in Short-Wave Logbooks—to determine just what stations are on the air in any particular band at the time you are operating your receiver Foreign Short-Wave stations frequently have available a number of different frequencies for transmission—and they shift from one frequency to another at different times of the day or in different seasons of the

COIL-WINDING DATA CHART

Wavelength covered with .00014 mfd. variable condenser	A	Secondary turns	B	C	Tickler turns	Wire Size (all plain enamel)
16-36	9/16"	5	⅞"	⅛"	4	#26
33-65	⅝"	12	⅞"	¼"	7	#26
57-115	½"	21	1"	¼"	9	#26
108-217	½"	52	close wound	⅛"	19	#26
190-300	⅜"	80	close wound	¼"	27	#28
250-550	¼"	160	close wound	¼"	35	#34

year. Some foreign stations transmit simultaneously on several frequencies; for example, the British Broadcasting Corporation transmits the identical program over stations GSB, GSC, GSD, and so on—each station being on a different frequency. Thus, if at any particular time conditions are such that you cannot pick up GSB, you may find that your set will bring in GSC because conditions are favorable for reception on its particular frequency. British stations—or other foreign stations transmitting in English—are easiest for the new DX'er to identify. But you will soon learn to recognize foreign language stations, like "Ici Paris Radio Coloniale," which means "This is Paris." And other stations, too, have easily recognizable catch-phrases. In addition, in many instances, the foreign announcer makes his announcement in English and French, as well as in his native language.

Since stations are crowded closely together on the Short-Wave portions of the dial, you must learn to tune very slowly and patiently in order to "pull in" the signals you want. This is a point which cannot be too strongly emphasized. Unless your Short-Wave set has provision for *bandspread* (an arrangement making it possible to spread out stations over a larger dial scale area), you must not expect to tune in foreign stations as you would local stations. Tune up and back very slowly within the precise area on the dial covering the frequency of the station you want. Often, if the dial needle is even the merest trifle away from the exact spot, you do not get the station you want; but a scarcely perceptible adjustment of the tuning knob will bring the station in "on the nose."

If, after careful tuning, it appears to be impossible to tune in a specific station at one time, try again on another occasion—because when atmospheric conditions change, the station may "come in like a local." Remember that even the big commercial radio networks—with all of their costly and elaborate equipment (much of which is specially built and runs up into enormous sums of money)—sometimes cannot pick up programs from abroad scheduled for rebroadcast simply because atmospheric conditions are unfavorable.

Static—which means simply disturbance caused by atmospheric electricity—is a matter over which we have no control. This, of course, applies only to "true" static. ("Man-made" static—disturbances caused by electric motors such as those used in electric shavers, vacuum cleaners, elevators, mixers, etc.,—can be entirely eliminated by efficient filter devices attached to the source of the interference, although these filters are also sometimes useful when used between the electric outlet and the radio set. Battery-operated sets are not usually affected by "man-made" static caused by the devices mentioned since such sets do not get their power from the electric line.)

During the winter months static is seldom as severe and as detrimental to good radio reception as it is during the summer. Accordingly, long-distance radio reception is almost always better during winter than during summer.

Another type of disturbance which affects reception is fading. This is encountered only on long distance reception and varies with time of day and season of the year. Circuits employing automatic volume control overcome this condition to some extent.

In spite of difficulties which are beyond our control, long-distance reception on the Short-Wave bands is constantly being improved as new circuits and new ideas are developed. And as the art of radio progresses, the Short-Wave bands will grow to be even more important than they already are today.

NOTE: In operating a regenerative receiver (a set of the type of the Knight DX'ER), a special tuning procedure is required. After the set has been turned on, wait a while for tubes to warm up. Then rotate the regeneration control knob until *oscillation* results. This is a phenomenom you can recognize by a single click followed by a hissing sound after you have passed a certain point in turning the knob. When oscillation begins, you have reached the sensitive point of the set for C.W. (code) reception. Then, turning the dial slowly, always readjusting the regeneration control to keep the set at the point of regeneration, you will find that your station comes right in.

To tune 'phone stations, you must keep the set *just below* the point of oscillation. This can be done by trying first for oscillation, then turning back until oscillation is gone, then working up again until you know that you are at the point just below oscillation. Then proceed to turn the tuning knob until you can hear the 'phone station very plainly.

A little practice with this procedure will soon make you an efficient short wave operator.

AMATEUR RADIO

We now come to a subject which could be treated adequately only in far more space than we have available. This is the subject of Amateur Radio. Since this book has been planned especially for the beginning radio builder and experimenter, and since there are already dozens of manuals for the Amateur, we shall confine ourselves to material of a rather general nature.

The Amateur (or "Ham," as he also calls himself) is the aristocrat of non-professional radio circles. Strictly speaking, an Amateur is a person who holds a Federal license to operate a transmitter on the radio bands restricted to non-commercial use. In order to obtain this license (issued by authority of the Federal Communications Commission) the prospective Amateur must meet a number of requirements which have been set up by the government to assure that all Amateur stations are competently operated.

The Amateur license is issued in three classifications: Class "C" license to those living more than 125 air miles from the nearest F.C.C. office. Examination is by mail. Class "B" licenses are issued to those living within the 125-mile area, and examinations are in person at the F.C.C. office. Requirements for both of these are the same. The ability to send and receive code at the rate of at least thirteen words per minute:

a technical knowledge of Amateur equipment; theory and operation; and a knowledge of the F.C.C. regulations relative to Amateur stations are the three chief requirements. Class "A" licenses are issued to persons who have held an Amateur license for at least a year and who have appeared in person at the regional F.C.C. office for additional examination on phone transmitters. Holders of Class "A" licenses are permitted to transmit in certain restricted frequency bands not open to Class "B" or Class "C" license holders.

In all cases, the Amateur operator must be a citizen of the United States and the Amateur station must be operated on premises not owned or controlled by an alien. There is no age limitation—and so Amateurs range in age from young boys of 12 or 15 to men and women over 60.

Full details of the license requirements and the addresses of your nearest F. C. C. office can be obtained by consulting one of the many Amateur books or by writing to ALLIED. (In Canada, details of requirements may be obtained from the Canadian Radio Commission, Ottawa, Ontario.)

For purposes of radio administration, the continental United States is separated into nine districts. Amateur station call letters are based on this separation. In the first place the prefix W was assigned to the United States by International radio convention. To this prefix is added the number corresponding to the district number. W9, for example, is the prefix for the district comprising the Midwest region. Added to this prefix are two or three letters, identifying the individual station.

The U. S. districts are:

W1—New England states: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont.

W2—North Central Atlantic States: New Jersey, Part of New York.

W3—Middle Atlantic States: Delaware, Maryland, Virginia, District of Columbia, Northwestern Pennsylvania.

W4—Southern Atlantic States: Tennessee, Alabama, Georgia, Florida, South Carolina, North Carolina.

W5—South Central States: Mississippi, Louisiana, Arkansas, Oklahoma, Texas, New Mexico.

W6—Pacific States: California, Nevada, Utah, Arizona.

W7—Northwest States: Montana, Wyoming, Idaho, Oregon, Washington.

W8—Great Lakes States: Pennsylvania, part of New York, West Virginia, Ohio, part of Michigan.

W9—Middle West States: Nebraska, Kansas, Iowa, Missouri, Colorado, Illinois, Indiana, Kentucky, North Dakota, South Dakota, Minnesota, Wisconsin, part of Michigan.

The K prefix is used for U. S. territories, including Alaska, Hawaii, Philippine Islands.

To secure the address of the radio inspector in your district, see any copy of the *Radio Amateur Callbook*, which also contains a complete listing of all amateurs in the entire world.

CODE

We have already mentioned the fact that a knowledge of radio code is required of all Amateurs. Learning this code and acquiring proficiency in transmitting and receiving in code should therefore be an early step in the procedure of every one who intends to become an Amateur. The Continental International Code used in radio consists of short signals (called *dots*) and long signals (called *dashes*) which are about three times as long in duration as the short signals. The following table shows the code for letters of the alphabet, for numbers, and for common punctuation marks:

LETTERS

• ▬	A	▬ •	N
▬ • • •	B	▬ ▬ ▬	O
▬ • ▬ •	C	• ▬ ▬ •	P
▬ • •	D	▬ ▬ • ▬	Q
•	E	• ▬ •	R
• • ▬ •	F	• • •	S
▬ ▬ •	G	▬	T
• • • •	H	• • ▬	U
• •	I	• • • ▬	V
• ▬ ▬ ▬	J	• ▬ ▬	W
▬ • ▬	K	▬ • • ▬	X
• ▬ • •	L	▬ • ▬ ▬	Y
▬ ▬	M	▬ ▬ • •	Z

NUMBERS

• ▬ ▬ ▬ ▬	1	▬ • • • •	6
• • ▬ ▬ ▬	2	▬ ▬ • • •	7
• • • ▬ ▬	3	▬ ▬ ▬ • •	8
• • • • ▬	4	▬ ▬ ▬ ▬ •	9
• • • • •	5	▬ ▬ ▬ ▬ ▬	0

PUNCTUATION

• ▬ • ▬ • ▬	Period
▬ ▬ • • ▬ ▬	Comma
• • ▬ ▬ • •	Question Mark

While the long and short signals are called dashes and dots, when heard over the air they sound like "dit" for the dots and "dah" for the dashes. The letter *P*, for example, sounds like "dit-dah-dah-dit." In learning the code, therefore, the letters should be memorized with the "dit-dah" sounds, not as "dot-dash,"

We lack the space to say very much about the process involved in learning the code. Furthermore, it is adequately covered in several books for the Amateur. However, we can suggest that a "code-learning" device or "code practice set" of some kind should be used. Inexpensive code practice oscillators are commonly available. Pressing the key produces a high-pitched note exactly like the sound of code as it is transmitted. The code learner can thus associate the "dit-dah" combination of sounds with each letter and fix the sound-

combination firmly in mind. If two persons work the set together, they can learn to send and to receive code in a short period of time and then to increase their efficiency by regular practice.

The listing below shows frequency allocations assigned exclusively for Amateur use. C.W. (code) signals are permitted in all of these bands. Phone transmission is permitted in portions of all of these bands except the 40-meter band.

The complete Amateur range is as follows:

1750-2050	K.C.	(160 meter band)
3500-4000	K.C.	(80 meter band)
7000-7300	K.C.	(40 meter band)
14000-14400	K.C.	(20 meter band)
28000-30000	K.C.	(10 meter band)
56000-60000	K.C.	(5 meter band)
112000-116000	K.C.	(2.5 meter band)
224000-230000	K.C.	(1.25 meter band)
300000	K.C.	and up

The Amateurs of the world maintain several organizations, the most noted of which is the American Radio Relay League (A.R.R.L.). A full description of this group, its aims, and its operation is included in the A.R.R.L. *Handbook* (see List of Books, Page 22). Amateurs have on several occasions rendered immeasurable service to our government and to our people. In times of disaster especially, as in the devastating floods of 1936, the Amateur station operators maintained the only contacts with the rest of the nation when almost all other communication facilities had failed. The newspapers frequently tell of how lives of persons in isolated localities are saved by Amateur radio communication.

But even aside from times of disaster and heroism, Amateurs are constantly active to improve the art of radio and to further fellowship and good will. The radio-builder and experimenter who passes beyond the beginning stages can well set as his goal the operation of his own Amateur station.

As this book is being printed, our country is at war. By order of the Federal Communications Commission, amateur transmissions have been curtailed for the duration. Amateurs, everywhere, are offering their services as radio men in the armed forces and organizing emergency communication nets for civilian defense. Again, as always, the amateurs are proving their value in time of need.

As mentioned before, there are several Amateur handbooks available which give much more complete information on how to become a licensed amateur operator. These handbooks may be purchased from ALLIED Radio Corporation or any of the many radio supply houses. They are published annually, bringing up to date many circuits on transmitters and receivers which would be impossible to cover within the pages of this booklet. One of the best educations on radio in general, may be obtained from them as their nearly 500 pages adequately cover theory, operation and actual construction of many "rigs" from small economical sets to quite elaborate ones.

The publisher of one of the amateur handbooks—American Radio Relay League—also publishes a monthly periodical devoted exclusively to amateur radio. It is known as QST and is subscribed to by nearly all amateurs. Each month new circuits and constructional articles are presented. While some of the articles are for the more advanced man, nearly half are generally devoted to items of interest to the beginner.

An example of the advanced type "Ham" station. The equipment consists of (from left to right): a high gain 2 stage preselector, a 12 tube communication receiver, a frequency standard, a variable frequency control for the transmitter, a direction indicator for a rotary beam antenna, and an 800 watt transmitter Directly in front of the operator is a crystal microphone and a "bug" (speed key).

A LIST OF COMMON ABBREVIATIONS

As you read circuit diagrams or radio magazines and books, you will frequently run across a good many abbreviations or symbols for radio terms. We believe that even the radio beginner ought to know the meanings of some of the more common abbreviations in general use. It is advisable that you become familiar with these terms.

A.C.	—Alternating current
A.F.	—Audio frequency
A.F.C.	—Automatic frequency control
A.M.	—Amplitude modulation
A.	—Ampere
Ant.	—Antenna
A.V.C.	—Automatic volume control
A.V.E.	—Automatic volume expansion
BC	—Broadcast
B.F.O.	—Beat frequency oscillator
C.	—Capacity
CW	—Continuous wave (used to refer to *code* transmission)
db	—Decibel (unit of measurement for sound)
D.C.	—Direct current
DX	—Long distance
E	—Symbol for volts
E_p	—Average plate voltage (D.C.) of a tube
E_f	—Filament or heater voltage of a tube
FM	—Frequency modulation
EMF	—Electromotive force (voltage)
Gnd.	—Ground
Ham	—Licensed Amateur
HF	—High frequency
Hy.	—Henry (unit of measurement for inductance)
I	—Symbol of current in amperes
I_p	—Average plate current (D.C.) of a tube
I.F.	—Intermediate frequency
KC	—Kilocycle (1000 cycles)
KW	—Kilowatt (1000 watts)
Meg	—Megohm (1,000,000 ohms)
Ma.	—Milliampere (1/1000 amperes)
Mc	—Megacycle
Mil	—One-thousandth
Mhy.	—Millihenry
Mike	—Microphone
Mfd.	—Microfarad (1/1,000,000 of a farad)
Mmfd	—Micro-microfarad (1/1,000,000 of a microfarad)
MU	—Amplification factor of a tube
Ω	—Ohm
P.A.	—Public Address
'phone	—Radiophone (voice transmission)
R	—Resistance
RF	—Radio frequency
R_l	—Plate load resistance of a tube
RMS	—Root Mean Square
SG	—Screen grid
Super	—Superheterodyne (a type of radio circuit)
SW	—Short wave
SWL	—Short wave listener (a radio fan who is not an Amateur station operator)
TRF	—Tuned radio frequency (a type of radio circuit)
UHF	—Ultra high frequency
V	—Volt
W	—Watt
X'mitter	—Transmitter
X'tal	—Crystal
Z	—Symbol for impedance

CONVERSION TABLE

MULTIPLY	BY	TO GET
Amperes	× 1,000,000	microamperes
Amperes	× 1,000	milliamperes
Cycles	× .000,001	megacycles
Cycles	× .001	kilocycles
Farads	× 1,000,000,000,000	micromicrofarads
Farads	× 1,000,000	microfarads
Henrys	× 1,000,000	microhenrys
Henrys	× 1,000	millihenrys
Kilocycles	× 1,000	cycles
Megacycle	× 1,000,000	cycles
Microamperes	× .000,001	amperes
Microfarads	× .000,001	farads
Microhenrys	× .000,001	henrys
Megohm	× 1,000,000	ohms
Microvolts	× .000,001	volts
Micromicrofarads	× .000,000,000,001	farads
Milliamperes	× .001	amperes
Millihenrys	× .001	henrys
Milliohms	× .001	ohms
Millivolts	× .001	volts
Ohms	× .000,001	megohm
Volts	× 1,000,000	microvolts
Volts	× 1,000	millivolts

A LIST OF USEFUL BOOKS

The following books are suggested as reference works for the student of radio, and as sources of further information for the advanced radio builder.

Allied Radio Corp.: *A Dictionary of Radio Terms.* Over 800 concise, easy-to-understand definitions of commonly used words in Radio, Electronics and Television. Fully illustrated. Contains detailed explanation on how to read schematic diagrams, historic data, etc. Highly recommended to Radio Students, Experimenters, and Beginners.

Allied's Radio Circuit Handbook. 19 of the most popular ALLIED "Build-Your-Own" diagrams in one book. Complete explanations of circuit functions. In addition there are 16 extra diagrams of basic radio circuits with explanation of their use in complex radio design.

Allied's Radio Data Handbook. Edited by Nelson M. Cooke, Chief Radio Electrician, U. S. Navy. Handbook of formulas, data, standards, tables and charts used in the solution of everyday problems in radio and electronics. Indispensable to everyone in radio.

Amateur Radio Relay League: *The Radio Amateur's Handbook.* The official handbook of the A. R. R. L., covering every aspect of Amateur radio from the beginning stages to advanced station operation. Valuable for all radio builders.

Ghirardi, A. A.: *Radio Physics Course.* A textbook offering a complete course in the theory of radio and television. Essential for the student who wants a sound background in radio theory.

Henney, Keith: *Principles of Radio.* A popular textbook in radio theory and practice.

Manly, H. P.: *Radio and Electronic Dictionary.* A useful reference book defining some 3,000 radio terms in clear, understandable language.

Editors and Engineers: *The "Radio" Handbook.* Covers all radio building and operating. An Amateur essential. Diagrams and instructions for building everything from a 1-tube receiver to a 1 K.W. transmitter.

Radio Corporation of America: *R.C.A. Tube Manual.* Complete technical specifications on all R.C.A. receiving type tubes. *R.C.A. Transmitting Tube Manual.* For the Amateur station operator.

For prices of above, and for lists of other useful books, consult your Allied catalog. Also see last page of this book.

RESISTOR COLOR - CODE GUIDE

The Radio Manufacturers' Association (R. M. A.) has adopted a standard system for coding resistors with colors to indicate the resistance value. Since resistors are used in all radio circuits, and since the values are indicated on the resistors by coloring, the radio beginner must learn how to read this color-code.

Three color indications are used. "Body" color is the color of the body of the resistor itself. "End" color is the color at the end of the resistor. "Dot" color is the color of a dot on the resistor. These stand for the resistance in this way: Body color represents the first figure of the resistance value; end color represents the second figure; and dot color represents the *number* of *zeros* following the first two figures.

For example, to indicate a resistance of 25,000 ohms, under the R. M. A. color-code system, a resistor would have a red body, a green end, and an orange dot. (Red stands for 2, green for 5, and orange for 3 zeros.)

The following table shows the values represented by the various colors:

Body Color (*1st Figure*)	End Color (*2nd Figure*)	Dot Color (*No. of Zeros*)
0—black	0—black	none—black
1—brown	1—brown	000000—blue
2—red	2—red	00000—green
3—orange	3—orange	0000—yellow
4—yellow	4—yellow	000—orange
5—green	5—green	00—red
6—blue	6—blue	0—brown
7—violet	7—violet	
8—gray	8—gray	
9—white	9—white	

Some resistor manufacturers use a slightly different arrangement for color-coding. Three separate color bands are used instead of the body, end, and dot method. The bands are painted on the left end of the resistor. The color coding reads from left to right. The first band represents the first figure; the second band represents the second figure; the third band represents the number of zeros following the first two figures. The same color values are used as above.

An inexpensive pocket-size guide with rotary discs showing body, end, and dot colors of resistors according to R. M. A. standard color-code can be purchased from ALLIED. This pocket guide shows the figure for each color on each scale so that resistance values can be obtained instantly.

Many manufacturers also mark small mica condensers with three colored dots following the same code employed for resistors. For condensers, all readings are in micromicrofarads (mmfd). A 250 mmfd. condenser (.00025 mfd.) would be coded as follows: red dot (2), green dot (5), brown dot (1 zero.)

SOME INTERESTING CIRCUITS

On the pages that follow we have included diagrams and construction notes on a number of circuits of special interest to radio builders. Four of the most popular circuits, based on demand and ease of construction, are represented.

Beside the two receiver circuits, two other circuits are included. The *Knight* 4-Watt AC-DC Amplifier is an easy-to-build audio amplifier. Although cost of construction is low, the amplifier may be used in a high-fidelity record player.

The 3 Tube Phono-Oscillator is a great little unit for home entertainment. It is actually a miniature broadcast station, transmitting with just sufficient power to be picked up in your own receiver.

The circuits of the "2 Tube DX-ER" on pages 24 and 25 and "Ocean Hopper" on pages 26 and 27 represent the best performance obtainable from only two tubes. Each is carefully designed, using modern tubes, and are real "DX getters." The "DX-ER" is for battery operation, and the "Ocean Hopper" is for operation from 110 volt AC or DC power.

Many other diagrams are available from Allied at a cost of only 5c each. Each diagram contains complete construction data, schematic and pictorial diagrams and a list of parts required to build the project.

In addition to these circuits, the beginner will find all type of sets described in construction articles in the current radio magazines and in other handbooks. Also, every ALLIED catalog devotes a number of pages to listings of construction kits, blueprints, and diagrams for hundreds of other sets. In every instance, a parts list showing a complete kit of matched parts for any circuit is available from ALLIED without charge.

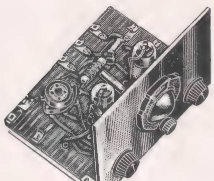
It might be pointed out here that it is not absolutely necessary to use the exact parts as specified in a construction article. As long as parts have the same electrical specifications, good results can be expected.

The construction notes on the following circuits are based on actual laboratory construction of these sets. In each case, the beginner should follow the instructions faithfully. Failure to do so may result in poor operation—or total lack of operation—of the circuits described. In all cases, both pictorial and schematic diagrams have been included to clarify as much as possible the exact procedure to be followed in wiring.

We wish to point out again that ALLIED kits are supplied complete in every respect, down to the last nut and bolt. There are no "extras" to buy. Chassis and panels are completely formed, punched and drilled. This simplifies the construction of a kit. Of course, it is not necessary to purchase the complete kit. If you have some of the parts for the circuit you plan on building, purchase those parts you need. In general, the only tools required are a soldering iron, a screw driver and a pair of pliers. It will probably be easier for the beginner to follow a pictorial rather than a schematic diagram. However, when constructing a kit, both the pictorial and schematic diagrams should be followed. In this way you will become familiar with the various symbols which represent radio components used in a circuit. In following your pictorial or schematic diagram cross off on the diagram the corresponding wire as it is connected in the circuit under construction. This will eliminate omissions in the wiring of the kit. If the foregoing points are kept in mind, the builder will have no difficulty in building the kits which are described on the following pages.

KNIGHT 2-TUBE "DX-ER"

The 2-Tube "DX-ER" is a dependable battery operated short-wave receiver which can be built quickly and easily. The tuning range is 9.5 to 550 meters when used with proper coils, covering the important foreign and domestic 'phone and code Amateur bands, as well as regular standard broadcast programs.



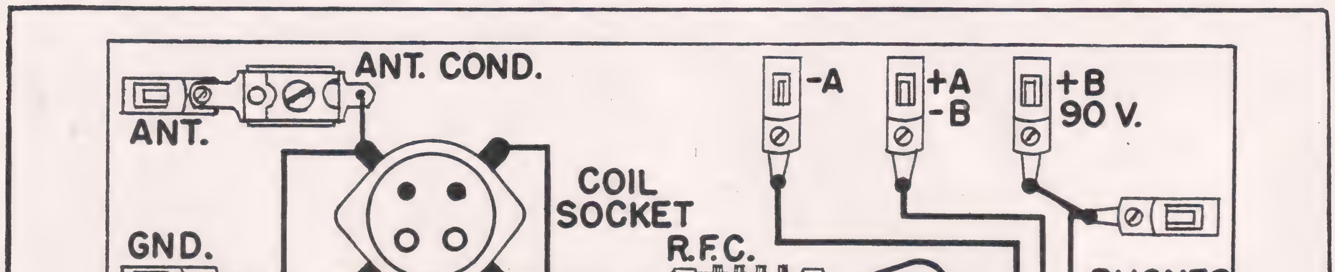
Before you begin to wire, you should mount all the parts as indicated on the pictorial diagram. This is extremely important for effective results. You can then start the wiring, following the schematic diagram and checking your work from time to time with the pictorial diagram. As you proceed, trace the completed connections with a colored pencil. This will help you to remember exactly which connections have already been made.

After the set has been wired and one of the coils and the two 1.4 volt tubes are in place, connect the "A" battery and notice the filament glow in the tubes. This will serve as a safety check to see if the filaments are wired correctly. No glow indicates that an error has been made in the filament circuit. When the filament glows connect the "B" battery and insert the headphones into the proper Fahnestock clips.

Now test the set to see if it will regenerate. Advance the regeneration control to the right, and a hiss will be heard. If you do not hear this hiss, check the coil socket and the "B" batteries to see that they are wired correctly.

Next, connect the antenna and ground. With these in place and the regeneration control just below oscillation (hissing point), turn the tuning control and you will receive several stations. You will find that adjusting the antenna trimmer will help a great deal. The antenna condenser should be adjusted so that the detector tube will oscillate at all points on the tuning dia.l The point of adjustment depends entirely upon the degree of absorption of the antenna circuit from the tuning circuit. Once the trimmer is adjusted for any one of the coils, no other changes need be made until

PICTORIAL WIRING DIAGRAM



KNIGHT 2-TUBE "DX-ER"

a different coil is used. This adjustment is not critical except when you actually want some real DX. It is worth mentioning here that a good aerial is essential for efficient short wave reception, particularly for a set of the "DX-er" type. Both the aerial and lead-in should be well insulated and kept as far away from walls, roofs, etc., as possible.

You will soon learn in using the "DX-er" that broadcast and amateur 'phone stations come in best when the regeneration control is below the point where oscillation starts. Code signals, however, come in best above this point. In working on the short wave bands, keep the set just oscillating, and tune very slowly. The incoming "dit-dit-dah" will tell you that you have a code station. A whistle, on the other hand, should serve as a warning to reduce the regeneration control setting, and then to listen to a 'phone station at this dial setting.

While there is nothing tricky about the operation of the "DX-er," it is well to spend some time in learning how to tune it to obtain best results.

$1.36

KIT OF APPROVED PARTS

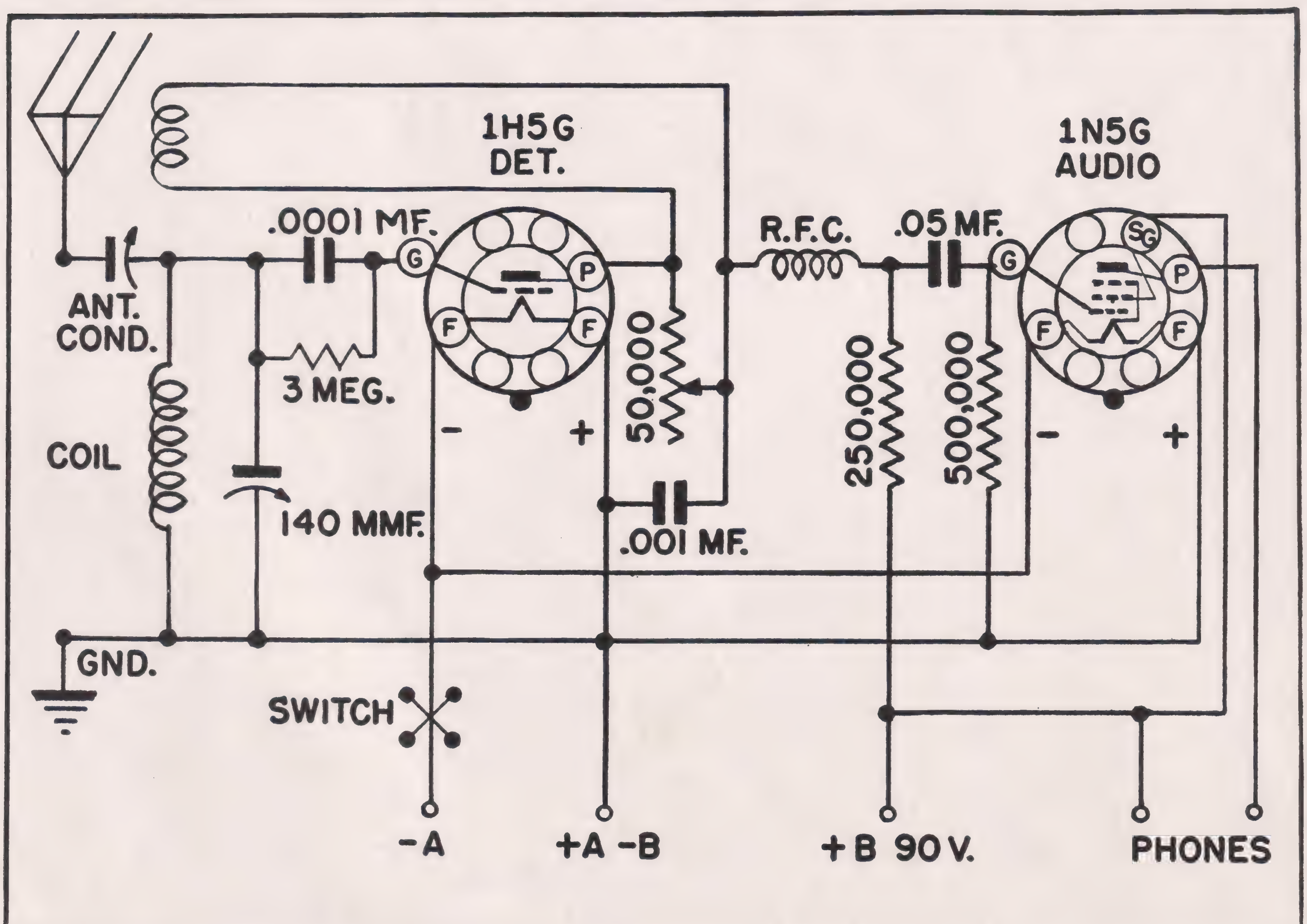
2N791	1	Knight 7 x 8 inch Masonite panel		$0.40
40-254	1	4 prong socket		.24
61-105	1	140 mmfd. variable condenser		.88
30-406	1	50,000 ohm regeneration control		.29
60-331	1	Antenna trimmer condenser		.10
60-800	1	Knight R.F. choke		.15
10-404	1	.0001 mfd. mica condenser		.08
10-415	1	.001 mfd. mica condenser		.12
1-800	1	3 megohm, ¼ watt resistor		.04
1-820	1	250,000 ohm, ½ watt resistor		.05
41-706	1	Package Fahnestock clips		.09
2N239	1	Baseboard, 6" x 8"		.20
55-321	1	Kurz-Kasch vernier dial		.75
55-150	2	Round knobs	@ .10	.20
1N615	1	Hardware kit		.20
34-141	1	Rotary "on-off" switch		.22
40-258	2	Octal sockets	@ .29	.58
10-460	1	.05 mfd. 400 volt condenser		.08
1-820	1	500,000 ohm ½ watt resistor		.05
42-036	2	Grip clips	@ .02	.04

ACCESSORIES

9-037	1	Knight type, 1H5G tube		.58
9-047	1	Knight type, 1N5G tube		.73
80-804	1	Knight 1½ volt dry cell		.29
80-800	2	Knight "B" batteries	@ 1.21	2.42
54-050	2	Plugs for "B" batteries	@ .04	.08
60-670	1	Kit of 4 coils for 9.5 to 217 meters		1.08
60-671	1	Kit of 2 coils for 190 to 550 meters		.95
59-111	1	American Bell 3000 ohm headphone		1.33

SCHEMATIC WIRING DIAGRAM

Diagram below shows top view of tube sockets.



KNIGHT AC-DC "OCEAN HOPPER"

This highly efficient radio is the latest version of the Knight 2 tube "Ocean-Hopper" series. Short wave stations from all over the world can be received with clarity and volume on this "easy-to-operate" receiver. Beam power output provides loud speaker performance on the stronger stations.

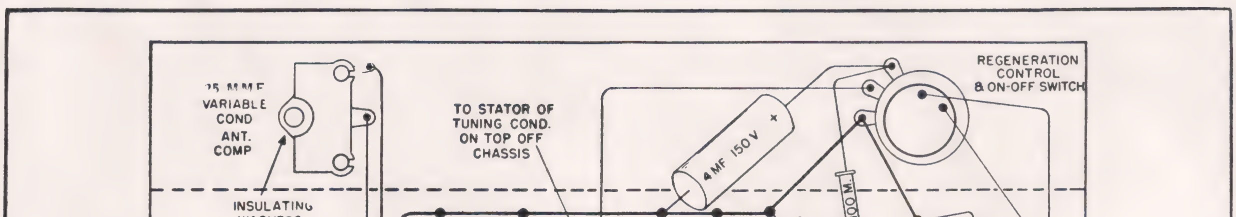
Four separate plug in coils are used for short waves, giving continuous wave length coverage from 16 to 195 meters. Two additional coils are used to cover the police and broadcast bands between 190 and 550 meters.

With the punched chassis provided with the kit, assembly is easy. Be sure that sockets are mounted with guide pin slots facing the directions shown. Do not forget to use the fiber insulating washers when mounting the antenna trimmer, as this condenser must be completely insulated from the chassis and panel.

Wiring the set is simplicity itself. The layout of parts provides short connections without any crowding. A heavy bus wire, running from one terminal of the coil socket to "pot" and phone post is used as common ground. This "ground" is by-passed to the chassis at one point only. It is a good idea to follow both the schematic and pictorial diagrams together to become acquainted with the reading of schematic diagrams. Diagrams of advanced receivers are usually shown in schematic form only. Mark off each connecting wire on the pictorial and schematic diagrams as each connection is made. This will aid in preventing duplicate wires and oversights.

For headphone operation be sure to connect the 2,000 ohm, 10 watt resistor to the two speaker terminals, on the outside of the chassis, plugging the headphones into the pin jacks provided. If a speaker is used, remove the 2,000 ohm resistor and connect the primary of a matching transformer to these speaker terminals.

Plug one of the broadcast coils into the four prong socket. Connect the lead-in of your aerial to the antenna binding post. Run a wire from the ground binding post to a cold water pipe. Plug the power cord into a 110 volt AC or DC power socket (if D.C. is used, it is sometimes necessary to reverse the plug in the outlet to obtain the right polarity) and turn the regeneration control knob a little to the right. You will immediately hear a click as the switch snaps on. Wait a few seconds



PICTORIAL-DIAGRAM

KNIGHT AC-DC "OCEAN HOPPER"

for the tubes to warm up. If no dull red glow is seen at the top of the tubes, the filaments are wired incorrectly and the wiring should be rechecked carefully.

If everything looks all right, advance the regeneration control until a thud and a hiss is heard in the earphones. This is the critical point of oscillation. Adjust the antenna trimmer for maximum amount of capacity possible and yet maintain the critical oscillating point over the entire tuning dial. This critical point is the setting for greatest sensitivity. Music and speech are received best with the regeneration control set just below the critical point of oscillation and code (C.W.) stations are received with the control just above this point.

Tune for a station with the main tuning dial at the same time maintaining this point of highest sensitivity with the regeneration control. After the signal is heard re-adjust the regeneration control for clearness.

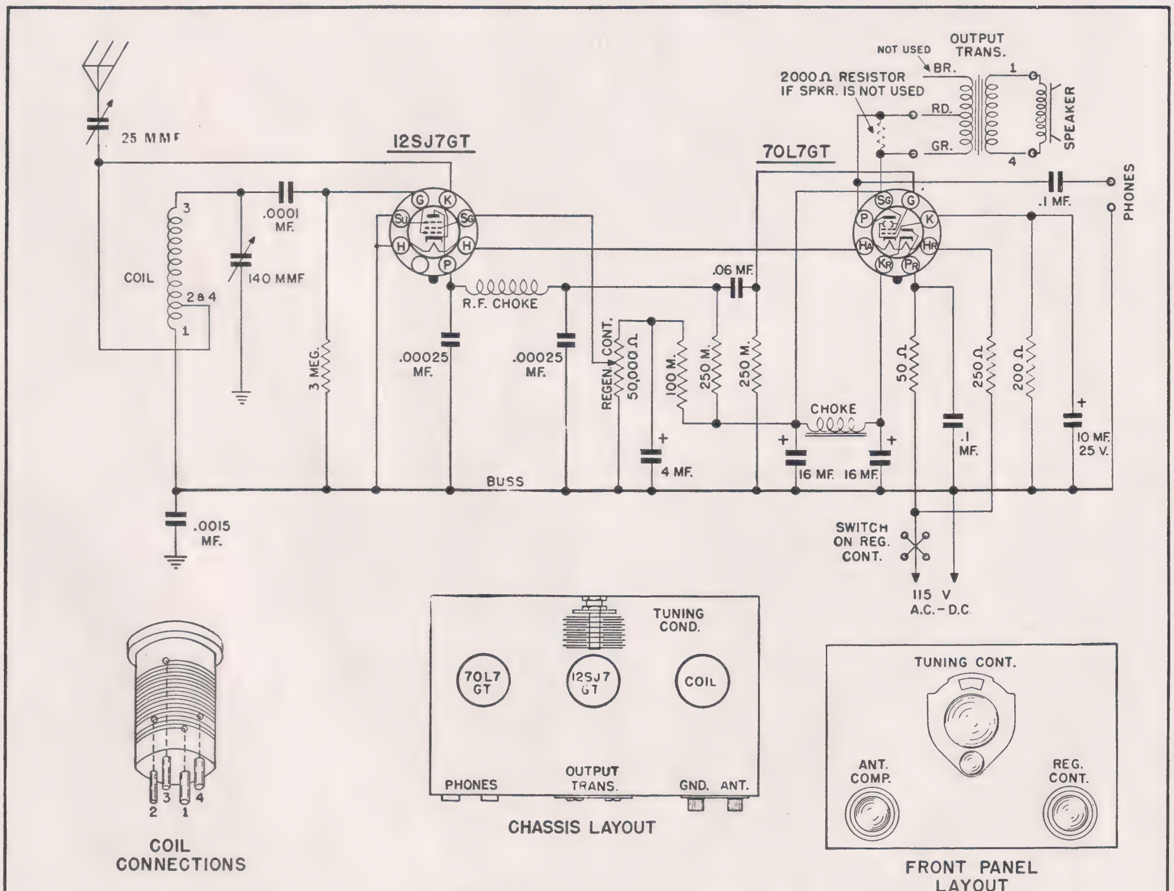
With a good high antenna 75 to 100 ft in length, this "Ocean-Hopper" receiver will literally "hop the ocean", bringing in stations from the four corners of the world, as well as the major stations of the United States.

KIT OF APPROVED PARTS

2N784	1	Punched and formed chassis, 5" x 8"		$1.10
2N783	1	Drilled Panel, 7" x 9"		.75
41-115	1	Black phone pin jack		.09
41-110	1	Red phone pin jack		.09
41-875	1	2-terminal speaker output connector		.09
41-366	1	"Ant.-Gnd." twin binding post terminal		.41
55-321	1	3" Kurz Kasch vernier dial		.75
55-150	2	Round knobs	@ .10	.20
61-101	1	Antenna trimmer condenser		.65
61-105	1	140 mmfd. variable condenser		.88
10-462	2	.1 mfd., 400 volt condenser	@ .10	.20
10-461	1	.06 mfd., 400 volt condenser		.08
10-407	2	.00025 mfd. mica condenser	@ .08	.16
10-404	1	.0001 mfd. mica condenser		.08
10-416	1	.0015 mfd. mica condenser		.12
10-233	2	16 mfd. 150 volt electrolytic	@ .30	.60
10-230	1	4 mfd. 150 volt electrolytic		.22
10-250	1	10 mfd. 25 volt electrolytic		.22
30-431	1	50,000 ohm potentiometer with switch		.44
1-820	1	50 ohm, ½ watt resistor		.05
1-560	1	250 ohm, 10 watt resistor		.18
1-840	1	100,000 ohm, 1 watt resistor		.06
1-840	1	200 ohm, 1 watt resistor		.06
1-820	2	250,000 ohm, ½ watt resistor	@ .05	.10
1-800	1	3 megohm, ¼ watt resistor		.04
60-800	1	2½ mh. R.F. choke		.15
62-000	1	25 hy. filter choke		.75
49-230	1	Line cord and plug		.18
41,850	2	2-lug wiring insulators	@ .03	.06
1N644	1	Kit of hardware, wire and solder		.15
40-228	2	Octal sockets	@ .05	.10
40-224	1	Four prong socket		.05
1-560	1	2,000 ohm, 10 watt resistor		.18

ACCESSORIES

83-312	1	Set of 4 coils, 16 to 195 meters	$1.35
83-313	1	Set of 2 coils, 190 to 550 meters	.70
83-311	1	Tube kit (1—12SJ7GT, 1—70L7GT)	1.40
83-314	1	5" P.M. speaker and output transformer	2.63
59-070	1	Pair 2,000 ohm phones	1.45



SCHEMATIC DIAGRAM

KNIGHT 4 WATT AMPLIFIER

A HIGHLY efficient, inexpensive audio amplifier can be built by you to give added pep to your short wave set or to permit loudspeaker reception with "headphone" receivers. The same amplifier may also be used for phonograph reproduction. A crystal or high impedance magnetic pickup may be connected directly to the input terminals.

The amplifier is designed for 110 volt, A.C.-D.C. operation. The four tubes used are wired in series, and the balance of the voltage is used in the ballast tube. Of course, for D.C. operation the proper plug polarity must be observed.

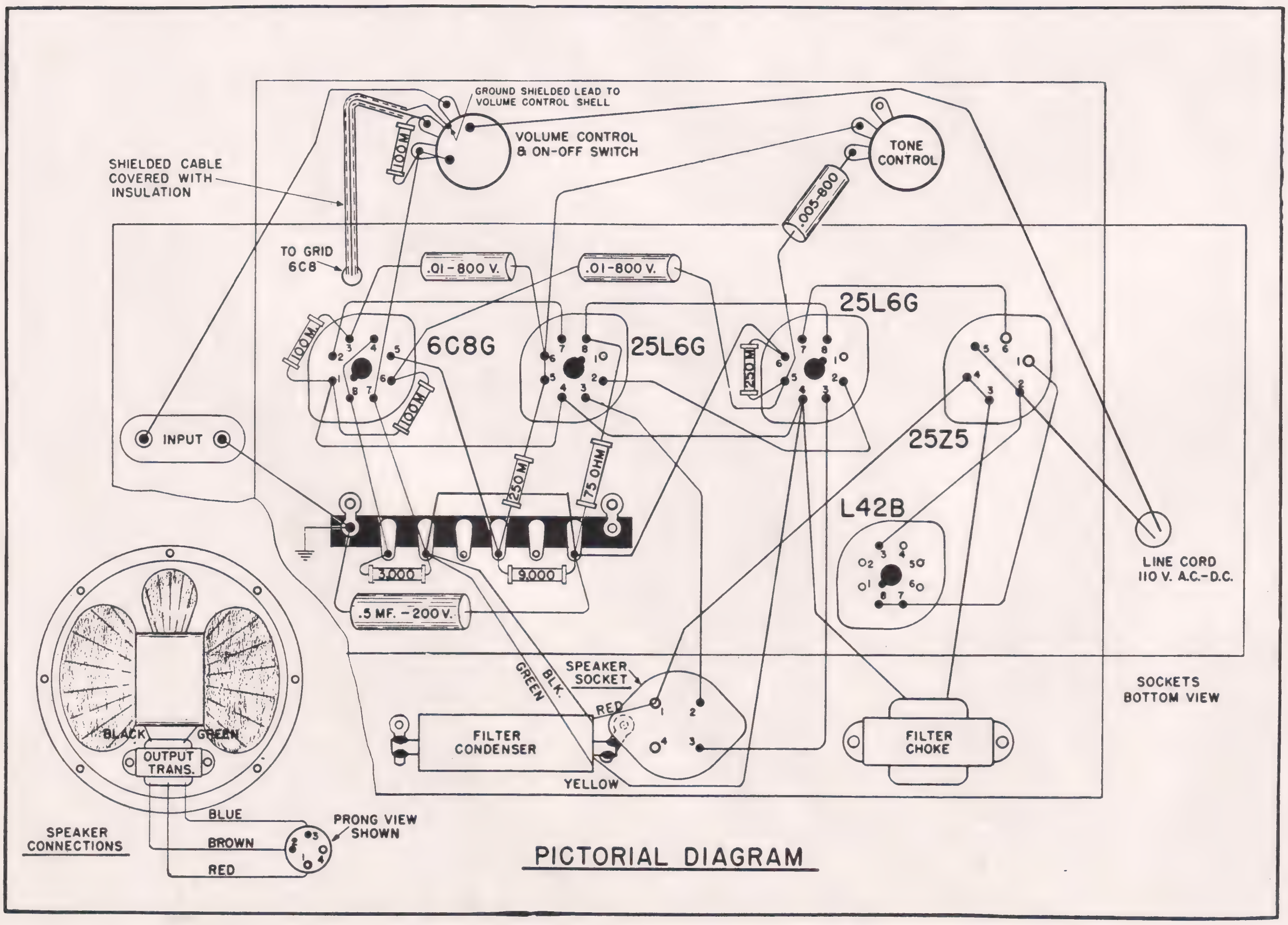
The circuit uses a type 6C8G tube in the *first audio stage* and also for *phase inversion.* For circuits where the plate voltage is about 110 volts, type 25L6 tubes are best for power output requirements. A 25Z5 tube serves as the half-wave rectifier.

An effective tone control is also incorporated in the grid circuit of the power output tubes. An extra switch is included on the tone control for phono motor, mikes, or anything else you may wish to turn on and off besides the line voltage. A 3½:1 audio transformer is required to couple the input to a radio.

The assembly of the amplifier is very simple since a drilled, formed chassis is supplied. The schematic diagram can be easily followed by the experienced builder, while the novice radio builder may use the pictorial diagram as an aid. Mount the parts, following the suggested layout in the picture diagram.

First of all, wire the filaments of the tubes. Include the wiring of the ballast tube and line cord so that the filaments can be tested for "light". To make this test, connect the line cord to an electric power outlet

PICTORIAL WIRING DIAGRAM



PICTORIAL DIAGRAM

KNIGHT 4 WATT AMPLIFIER

and turn on the switch. A glow will be noticed in the tubes, if the wiring has been correctly made.

The other wiring may be completed in any order. Use a colored pencil to check off the wiring completed. This guide will let you know at all times how you are getting along.

An external P.M. (permanent magnet) type speaker should be used. These speakers can be secured in several different physical sizes and with the correct output transformer to present 2,000 ohm load to the output stage.

Radio experimenters and short-wave fans will find this amplifier an interesting and useful project, both in the building and in the application.

$20.00

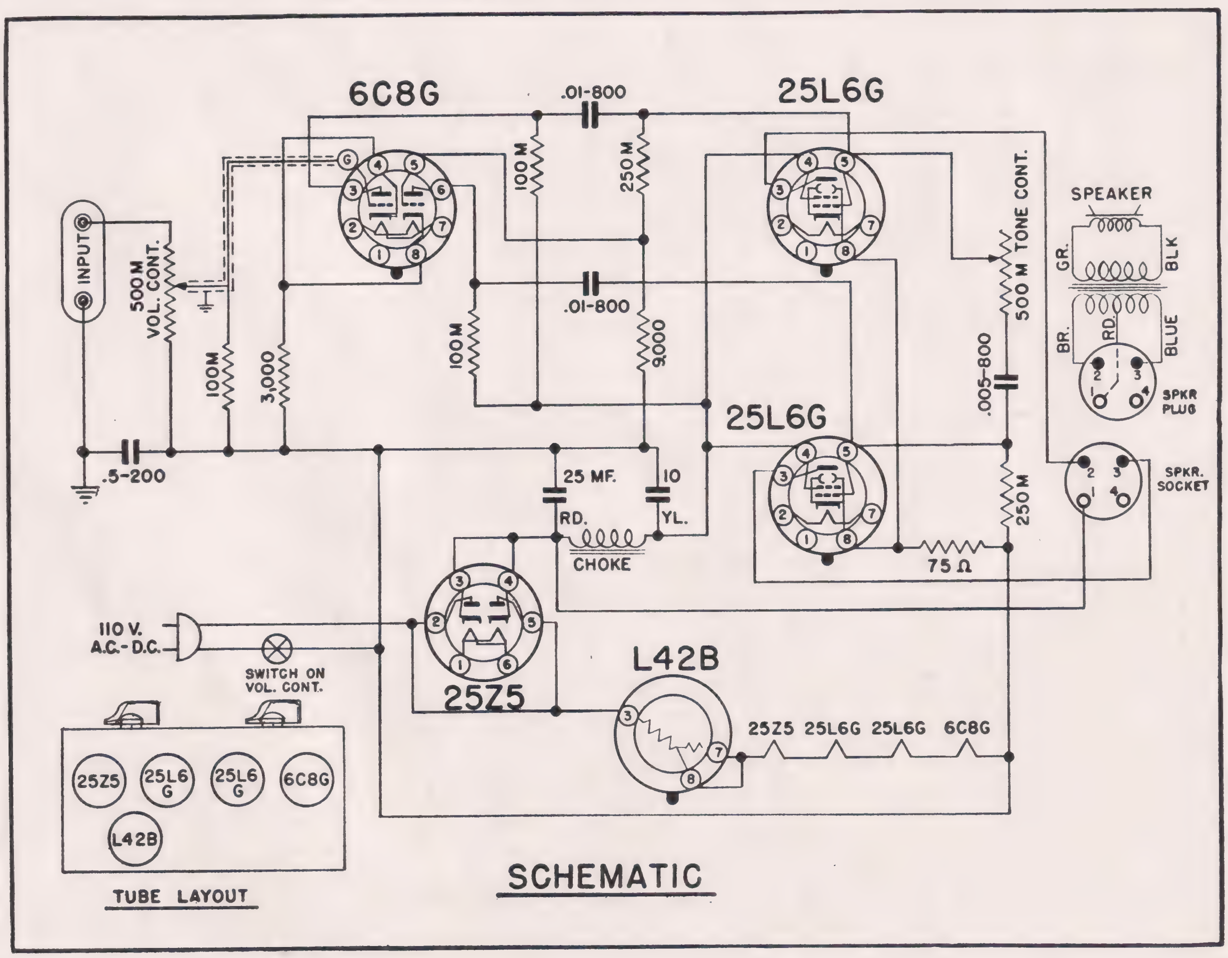
KIT OF APPROVED PARTS

1N050	1 Formed and drilled chassis, black crackle finished, 8"x4"x2½"	$1.25
1N051	1 2 section filter condenser	1.15
55-172	2 Dial plates @ .14	.28
40-228	4 Octal wafer sockets @ .05	.20
40-224	1 4 prong wafer socket	.05
40-226	1 6 prong wafer socket	.05
62-010	1 15 henry filter choke	.42
49-230	1 Line cord and plug	.18
30-434	1 500,000 ohm volume control with switch	.44
30-409	1 500,000 ohm tone control	.29
41-377	1 Tip jack input strip	.07
41-870	1 6 terminal connection strip	.04
1N052	1 Package hardware, solder and wire	.25
10-443	1 .5 mfd., 200 volt condenser	.17
10-484	1 .005 mfd., 600-800 volt condenser	.08
10-486	2 .01 mfd., 600-800 volt condensers @ .08	.16
1-820	3 100,000 ohm, ½ watt resistors @ .05	.15
1-820	2 250,000 ohm, ½ watt resistors @ .05	.10
1-820	1 9,000 ohm, ½ watt resistor	.05
1-820	1 3,000 ohm, ½ watt resistor	.05
1-860	1 75 ohm, 3 watt resistor	.11
55-074	2 Knobs @ .06	.12

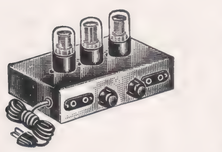
ACCESSORIES

93-005	Knight Tube Kit (1-6C8G, 2-25L6G, 1-25Z5, and 1-L42B)	$2.57
83-356	8" PM speaker and output transformer	3.76
62-055	Standard interstage audio transformer, Ratio 3½ to 1	.85

SCHEMATIC WIRING DIAGRAM



KNIGHT 3 TUBE PHONO OSCILLATOR



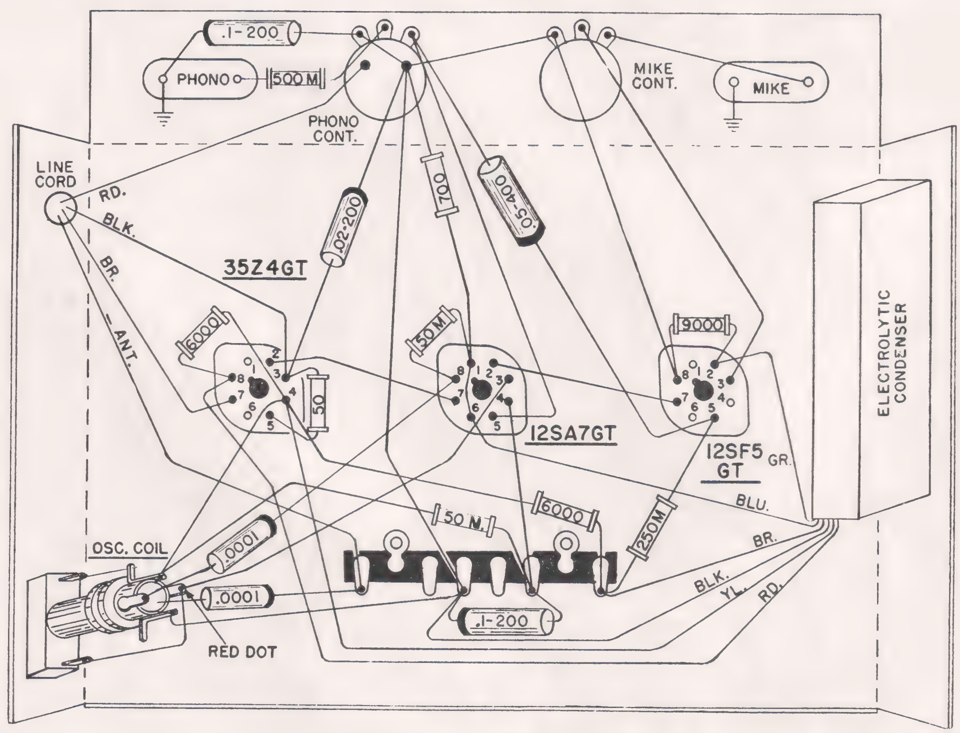
This phono player is a deluxe wireless oscillator type with many unusual features that make it exceptionally versatile. Two inputs are used, one providing more amplification than the other. One is used for connecting a phonograph pick-up of the crystal or magnetic type, and the other for a dynamic or crystal microphone. Each input is independently controlled by separate volume controls.

This is a great little unit for home entertainment. Phonograph records may be played alone or "mixed" with the microphone channel. This means that a person can sing or otherwise accompany any recording through his home receiver.

With a little ingenuity many interesting stunts can be devised. For example, you can arrange an "Amateur Hour." With the oscillator, an electric phonograph unit, and a microphone set up in another room you can put on a broadcast which apparently comes from one of the standard broadcast stations. The oscillator will perform successfully from any distance up to 50 feet from your set.

Assembly and wiring is simple. Mount the parts on the chassis exactly as shown in the pictorial diagram. Mount the oscillator coil last so that it will not be damaged during assembly. While wiring this unit, do not be over-anxious to complete the job in a hurry. Take your time. Do the work as neatly as possible. This practically eliminates any possibility for error and makes a final check-up very easy.

When wiring is completed, uncoil the antenna wire, put the tubes into the proper sockets and plug the oscillator into a 110 volt AC or DC outlet. Now turn on your radio and set the tuning dial to a spot in the broadcast band between 550 KC and 700 KC. The regular volume control on your radio should be set at normal volume. Now go back to your oscillator and connect your record player or microphone into the proper input. While playing a record, or speaking into the microphone, adjust the trimmed condenser through the opening on the left until the music or voice is heard in the radio. A small screwdriver is



PICTORIAL DIAGRAM

used for this adjustment. The volume control on the oscillator must be turned up during the tuning.

Any high-impedance, high output microphone may be used in the microphone channel. The inexpensive Quam or ICA dynamic microphones listed in the Allied catalog will work nicely. The new Shure and Astatic economy crystal mikes may also be used.

We must caution you not to use this unit with an outside antenna or attempt to transmit outside of your own home. The antenna furnished with the kit is sufficient for home entertainment purposes, and it should not be lengthened.

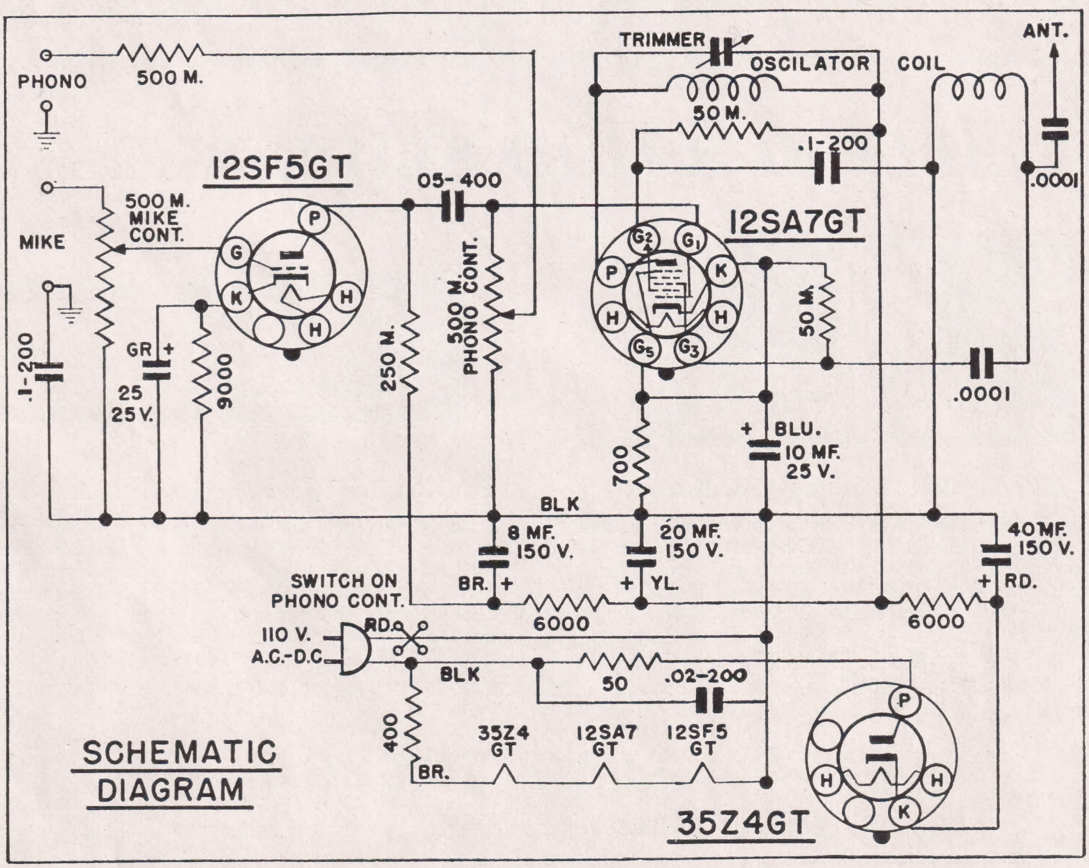
KIT OF APPROVED PARTS

$5.29

1N060	1	5 section filter condenser		$1.38
2N279	1	Oscillator coil		.95
27-041	1	500,000 ohm volume control with switch		.88
27-016	1	500,000 ohm volume control less switch		.59
41-379	2	Input tip jacks	@ .07	.14
41-870	1	6 point wiring strip		.04
1N059	1	Formed and drilled chassis, 8⅛" x 5" x 2"		.95
1N058	1	400 ohm line cord and plug		.45
48-360	1	Roll indoor antenna wire		.20
40-228	3	Octal sockets	@ .05	.15
10-430	2	.1 mfd. 200 volt condensers	@ .10	.20
10-460	1	.05 mfd. 400 volt condenser		.08
10-457	1	.02 mfd. condenser		.08
10-404	2	.0001 mfd. condensers	@ .08	.16
2-000	1	700 ohms, ½ watt resistor		.03
1-820	1	9000 ohms, ½ watt resistor		.05
1-820	2	50,000 ohm, ½ watt resistors	@ .05	.10
1-820	1	250,000 ohm, ½ watt resistor		.05
1-820	2	6,000 ohm, ½ watt resistors	@ .05	.10
1-820	1	50 ohm, ½ watt resistor		.05
1-820	1	500,000 ohm, ½ watt resistor		.05
1N056	1	Pkg. of hardware		.25

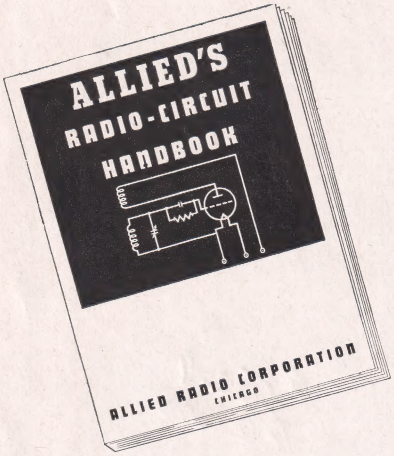
ACCESSORIES

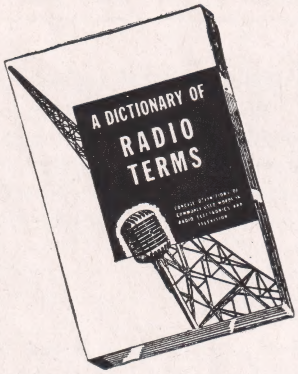
83-381	Kit of 3 tubes for above	$1.43
59-310	Quam microphone	2.23

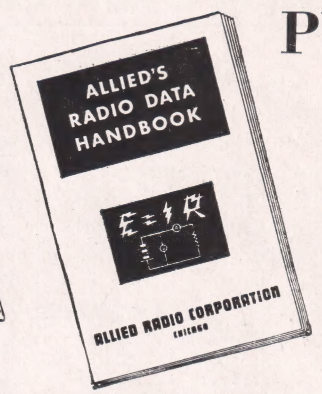


SCHEMATIC DIAGRAM

OTHER *ALLIED RADIO* PUBLICATIONS



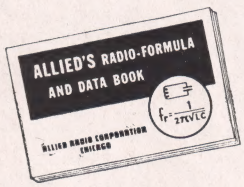




RADIO CIRCUIT HANDBOOK

This book teaches the principles of radio by analyzing "Basic Circuits" and explaining their function in the receiver, transmitter and electronic device. Thus the student learns why different circuits operate. Basic circuits covered are Oscillators, Detectors,, Power Supplies, Filters, Amplifiers, AVC, Phase Inverter. 32 pages, 8½″ x 11″.

37-753. Postpaid in U.S.A. 10c



ALLIED'S DICTIONARY OF RADIO TERMS

Miniature radio encyclopedia. Explains over 800 commonly used terms in Radio and Electronics. Invaluable for students, instructors and advanced radiomen. Additional material includes schematic symbol chart, notes on how to read schematic diagrams, formulas for resistors and condensers, Ohm's law, and an RMA color-code guide. 36 pages; handy 6″ x 9″ size.

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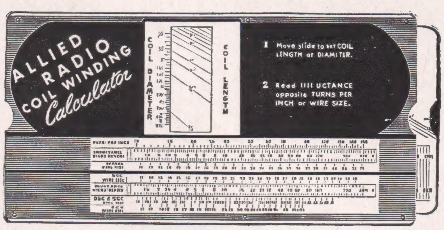

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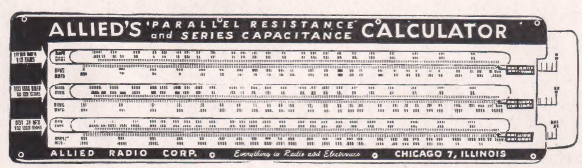

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